ARMY RESEARCH LABORATORY

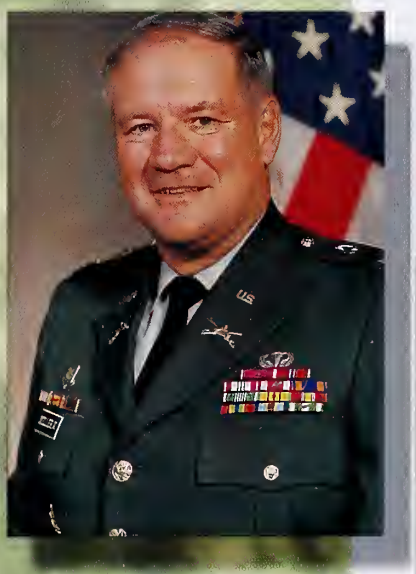



ANNUAL REVIEW

ARL 1993 Annual Review

Dr. John W. Lyons, Director
U.S.. Army Research Laboratory

Contents

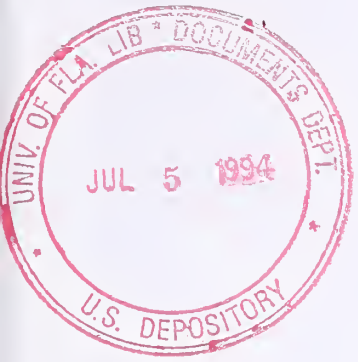


Colonel William J. Miller
Deputy Director

Larry D. France
Command Sergeant Major

A Message from the Director

I am delighted to greet you as the director of the U.S. Army Research Laboratory (ARL). During the period from 1 October 1992 to 30 September 1993, ARL has made many significant contributions to the Army. The normal stress and tension associated with ARL's reorganization have been compounded by the profound changes within the defense establishment following the end of the Cold War. These changes resulted in a series of budget cuts and personnel adjustments. Nevertheless, ARL has continued the high tradition of excellence of its progenitor organizations and has completed its first full year with numerous technical accomplishments and management innovations.



ARL's technical accomplishments show great potential of not only military but also industrial importance. Much of our research spans several business areas and involves cooperative efforts with Army, Defense, academia, and industry. The following is a selection of the technical accomplishments highlighted in this review:

- Advanced Composite Material and Processes—Patents submitted this year in the area of composites include a smart weave process and a textile technology for molding single-layer fabrics to net shapes. We anticipate that the innovative research being accomplished at ARL will ultimately reduce the weight and cost of composites while increasing the strategic mobility of Army systems.
- Digitizing the Battlefield—This has proven to be an exciting area of research at ARL. Advances such as the Mobile Integrated Tactical Terminal and the Commander's Visualization Research Tool are examples of research that will provide tactical commanders with tools to receive, process, and distribute critical intelligence information in digital format on high-resolution displays.
- Enhanced Simulation—One of the many uses of massively parallel computers at ARL has been the development of the geotypical high-resolution dynamic terrain model and the Battlefield Emission and Multiple Scattering model. These models promise great potential for enhancing training and simulation capabilities for the Army.

Support to ARL's customers remained of paramount importance. We cemented our relationship with our primary customers, the Research, Development and Engineering Centers, by executing 92 Technology Program Annexes (support agreements) and by allocating over 50 percent of our mission program to the solution of specific technical problems that they identified. Our work with the TRADOC Battle Labs is essential both to focus our scientific efforts on real battlefield problems and to speed emerging technology into advanced concepts that can be evaluated by experienced soldiers.

I have been working with the ARL executives to hone the ARL mission and to craft a vision for the future. While our basic areas of endeavor will remain the same—basic research, technology development, and analysis—we will be shifting our focus somewhat more to the longer view, i.e., to fundamental studies of new and emerging areas with the potential to insure that the balance of technology remains in favor of the United States.

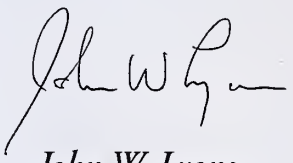
We have chosen to articulate this mission as "Execute fundamental and applied research to provide the Army the key technologies and analytical support necessary to assure supremacy in future land warfare."

Our vision of the future ARL is

- A laboratory that is preeminent in key areas of science and engineering relevant to land warfare.
- A staff that is widely recognized as outstanding.
- A partner with the Defense community, close to Army users and seen by them as essential to their missions.
- An intellectual crossroads for the technical community, intensively interacting with academe, industry, and other government laboratories in the U.S. and abroad.

I am convinced of the soundness of the concept of a single, central laboratory for technology base support of Army materiel. I am greatly impressed by the strength of our technical and support staffs. Additionally, ARL is well positioned to achieve the objectives set forth in the Army Science and Technology Master Plan.

I am pleased to submit this Annual Review in the spirit of pride in our past accomplishments and of optimism for an even brighter future.



John W. Lyons
ARL Director

ARL Board of Directors

A vital objective of our business planning process has been to provide responsive support to our principal customers who rely on ARL's mission-funded work to satisfy their technology and analysis needs. The Board of Directors (BOD), chartered by the AMC Deputy Commanding General in February 1993, is cochaired by the AMC Principal Deputies for Technology and Acquisition. The Director of ARL and the Technical Directors of our 13 principal customers serve as the permanent members of the ARL Board of Directors.

The ARL BOD's purpose is to ensure relevance of ARL's technology development activities to customer needs by validating that at least 50 percent of ARL's 6.1 (basic research) and 6.2 (exploratory development) mission resources qualify as supporting these organizations.

ARL Board of Directors

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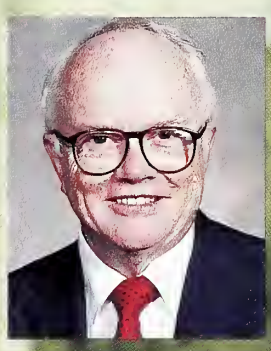

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Technical Achievements

For ARL, 1993 provided a new beginning in turbulent times. Budget cuts and personnel reductions were being imposed as ARL was officially being created with Dr. Lyons as the new director.

During this first challenging year, ARL maintained excellence in research, development, and analysis. The following highlights of technical accomplishments are evidence that providing the Army with superior technology for the next generation of systems, even through chaotic times, is a mission that ARL accepts.

Sensors, Signatures, Signal and Information Processing

"Providing the fundamental science and technology to *see, understand,* and *manage* the battlefield is the mission of the S3I Directorate. Research is conducted across the full spectrum of sensors, signal processing, automatic target acquisition, and information processing."

Vito DeMonte
DIRECTORATE EXECUTIVE

(301) 394-2100

Ultra-Wide-Band Foliage-Penetrating Synthetic Aperture Radar

A program is under way with the goal of developing and demonstrating ultra-wide-band radar concepts and algorithms capable of detecting and classifying stationary tactical targets concealed by foliage. During the past year, a rooftop measurement testbed was fully assembled and integrated with a gallium arsenide avalanche switch provided by the Boeing Company. A two-way measurement program began in January, with several collections completed later. Goals of the measurement effort include obtaining signatures from various tactical targets, as well as evaluating seasonal factors.

IMPACT: Successful development of this technology will allow the Army to detect, locate, and classify/recognize high-value, high-priority targets in deep hide. Transition to CECOM is planned for FY97.

Mobile Integrated Tactical Terminal Development

We have been instrumental in the design and development of the Mobile Integrated Tactical Terminal (MITT) for the Army Space Program Office. The Mobile Integrated Tactical Terminal is the U.S. Army's most advanced system for the Tactical Exploitation of National Capabilities (TENCAP) and is currently being fielded worldwide. The terminal receives, processes, and distributes critical intelligence products for the Army. ARL's pioneering work in open systems hardware and software is firmly embedded in these systems, allowing for unprecedented flexibility and growth potential.

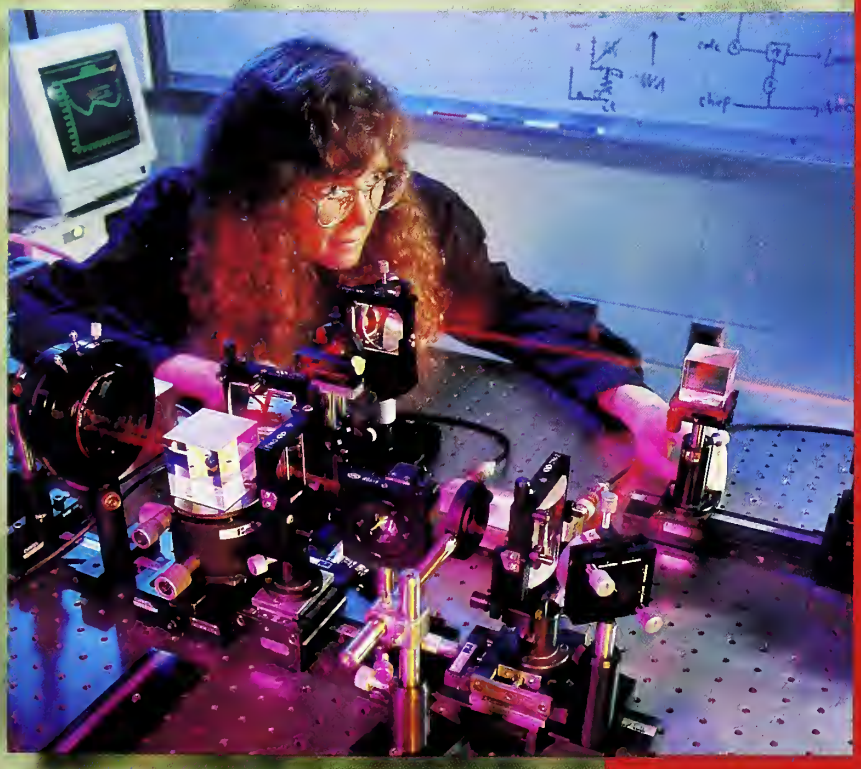
IMPACT: The Army is now fielding an extremely mobile, powerful, and flexible intelligence asset. Other critical Army initiatives, such as mobile tele-medical applications and the common ground station, will use significant portions of the MITT technologies.

Second-Generation Model-Based Multisensor Fusion

The Army needs to be able to quickly identify military targets as friend or foe. We have been developing a radical new approach to the aided (or automatic) target identification (ATI) problem: relational template matching. This approach uses not only the information contained in the sensed image but also information modeled about the targets that we are interested in identifying. We have demonstrated this new technology in the laboratory on a Sun-type workstation, using second-generation forward-looking infrared (FLIR) imagery collected under the Army's Comanche effort.

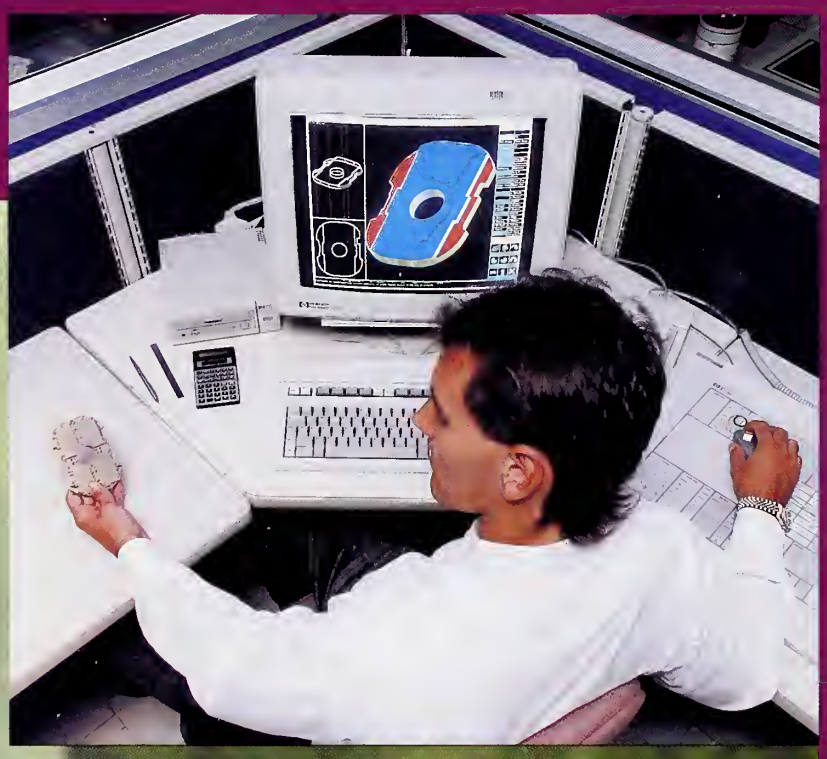
IMPACT: The successful development of this new technology will help the Army to accurately identify targets as friend or foe; this technology will also provide target aspect identification to aid in precise kill actions, thus supporting the Army's Combat Identification (CID) requirements.

The Army has the need to detect and locate stationary tactical vehicles on the battlefield, especially targets employing camouflage, concealment, and deception techniques such as hiding under heavy tree cover. The Ultra-Wide-Band Foliage-Penetrating Synthetic-Aperture Radar testbed, a roof-top, rail-guided measurement system, is being used to collect fully polarimetric ultra-wide-bandwidth signatures for an array of test objects, both in and out of "deep hide."



ARL's research in optical processing and photonics technology is aimed at improving signal processing capabilities in a variety of systems and components, including spectrum analyzers, acousto-optic correlators, and image processors. The primary advantage of optical signal processing is its ability to perform correlation of wideband signals rapidly and with high processing gain. The Acousto-Optic Range-Doppler Processor pictured left is designed to be smaller, weigh less, and require less power than processors employing other technologies.

ARL's pioneering work in open systems architecture has allowed us to design and produce tactical information processors that have unprecedented flexibility and growth potential. One of the Army's most advanced systems, the Mobile Integrated Tactical Terminal, receives, processes, and distributes critical intelligence products in digital format on high-resolution displays for use by tactical commanders.



Microwave and millimeter-wave devices have significant potential to improve capabilities in applications such as radar, communications, remote sensing, and imaging. Predictive modeling and simulation are absolutely essential for the creation of these devices and the achievement of high production yields. An ARL scientist is pictured left applying predictive modeling to the design, prototyping, and testing of microwave devices before actual fabrication.

Diffractive Optical Elements

Diffractive optical elements use diffraction, as opposed to refraction, to realize arbitrary optical processing functions, including focusing, filtering, and beamsplitting. We have developed techniques for the design and fabrication of diffractive optical elements that have arbitrary responses. In particular, we have developed algorithms to design binary-phase diffractive elements that can realize complex transfer functions with low error and high diffraction efficiency.

IMPACT: Conventional optical systems incorporate refractive elements that are difficult and expensive to fabricate, as well as being relatively large and heavy. Lighter, more easily manufactured diffractive optical elements will result in smaller, lighter weight optical systems with improved performance.

Electronics and Power Sources

"At the Electronics and Power Sources Directorate, we conduct research, development, and integration of advanced electronics and power sources technology to ensure U.S. military superiority through the year 2000 and beyond."

Dr. Clarence Thornton
DIRECTORATE EXECUTIVE

(908) 544-2541

High-Resolution, Lightweight Virtual Environment Interface

A virtual reality testbed system is being developed that includes interfaces for the next generation of display devices. The next-generation virtual reality displays are anticipated to include active-matrix thin-film electroluminescent and single-crystal silicon active-matrix liquid-crystal display 40-line/mm devices.

IMPACT: The testbed and interface will serve as a testing platform for virtual reality helmets and other state-of-the-art interaction devices under realistic conditions.

Millimeter-Wave Camera Technology

We are developing state-of-the-art millimeter-wave devices to enable passive sensing in poor visibility conditions. The objective is a millimeter-wave focal plane array to achieve high detection, with high resolution, of otherwise invisible targets. State-of-the-art submicron devices and monolithic integrated microwave receiver chips were used in demonstrating the millimeter-wave focal plane array concept.

IMPACT: Passive millimeter-wave cameras will provide real-time "video" images to pilots and weapons officers for landing, navigation, and targeting in poor visibility conditions such as fog, smoke, and snow. They will also be useful in fully covert operations.

Automatic Synthesis Tool for VLSI Chips

We expanded the institutionalization process for electronic design automation methodology through the development of an initial draft of a comprehensive VHSIC (very-high-speed integrated circuit) hardware description language modeling handbook and a computer-aided design synthesis tool for very-large-scale integration (VLSI). This tool enables the design and fabrication of integrated circuits from a high-level description of the circuit's required function.

IMPACT: The new synthesis tool has significantly increased capability over existing industry synthesis tools that work from high-level structural, rather than behavioral, descriptions.

Voltage-Tunable Infrared Photodetector

We designed a voltage-tunable, three-color, quantum-well infrared photodetector that is useful in discriminating among targets that have different infrared signatures. The detector uses electron inter-subband transitions in a strongly coupled asymmetric double quantum-well superlattice. The spectral response can be selected by tuning of the detector bias voltage through a range from 4 to 10 V. Detectivity is good and dark current is low, permitting the detector to be used with currently available circuitry.

IMPACT: The new photodetector will provide infrared discrimination capability to current devices.

Two-Cell Rechargeable Lightweight Battery

A high-energy battery that can be recharged at least 50 times is needed for low-cost training of the Special Operations Forces on the use of the AN/PAS-13 Thermal Weapons Sight. To fill this need, we have developed a metallic-lithium/nickel oxide rechargeable battery that provides 33 W-hr per cycle at a fifth the cost of throwaway batteries. Further, the energy content of the new battery is almost equivalent to that of primary throwaway batteries (37 W-hr). Thirty prototype batteries have been delivered, and testing is under way.

IMPACT: This battery will cut the cost of AN/PAS-13 training.

Battlefield Environment

"Battlefield Environment is a dynamic directorate focused on 'Owning the Weather (OTW)'—the warfighters' new edge in land force dominance. Our goal is to provide battlefield decision makers weather data, forecasts of battlefield environmental conditions, and analysis of the effects on friendly and enemy systems, operations, and tactics, so that they can gain a decisive advantage over opponents. OTW enables warfighters to fully exploit tactics that maximize the weather-derived technological advantages of our systems over the systems of hostile forces."

Don Veazey
DIRECTORATE EXECUTIVE

(505) 678-1225

Mobile Profiler System

A Technical Demonstration Mobile Profiler System was developed and field tested, satisfying the requirements of the Field Artillery Target Area Meteorology Sensors System Mission Need Statement. The Mobile Profiler System uses a combination of ground-based sensors and data from meteorological satellites to derive vertical profiles of atmospheric parameters needed to compute ballistic corrections for artillery shells. The Mobile Profiler System was successfully field tested during an air pollution experiment in the Los Angeles basin.

IMPACT: The Mobile Profiler System will be able to solve the time-staleness problem inherent in the balloon-based systems now in use to support the Field Artillery, while extending the aerial coverage for deep attack employment of smart munitions and submunitions. The system also has great potential in the civilian sector for monitoring air quality regulatory compliance and emergency pollution episodes. Technology developed for use in the Mobile Profiler System is already finding civilian applications in NOAA's profiler network.

Optical Turbulence Simulator

A new hybrid optical/digital processing technique was developed to simulate the effects of atmospherically induced phase distortions on imaging systems performance at faster-than-video rates. This technique is based on previously unavailable Russian technology, and makes use of a nonlinear optical two-dimensional feedback system with controllable statistical properties. The feedback system produces a spatially and temporally varying chaotic phase distortion.

IMPACT: This Optical Turbulence Simulator offers a cost-effective, efficient, and accurate method to allow dynamic simulation of atmospheric effects, enhancing both combat system and training device development. In addition, this technology offers the first real potential for passive mitigation of atmospheric effects over the near-horizontal paths in the first kilometer of the earth's atmosphere.

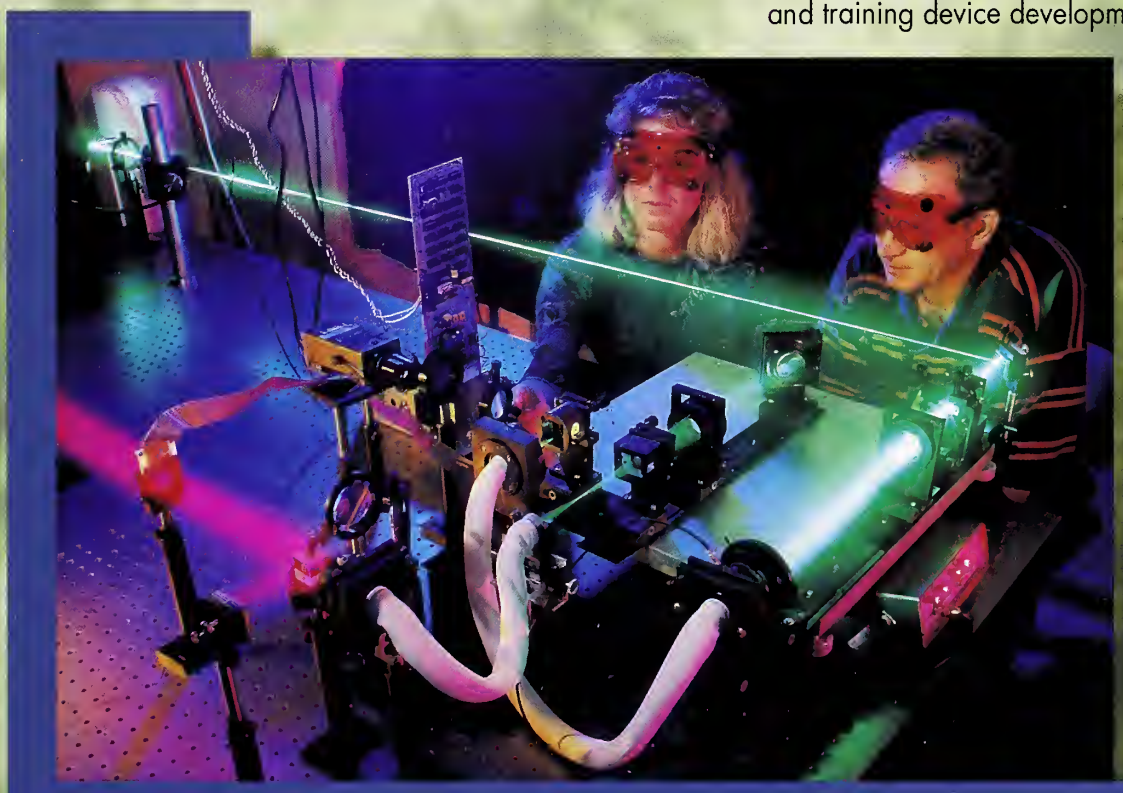
Transport and Diffusion for Theater Missile Defense

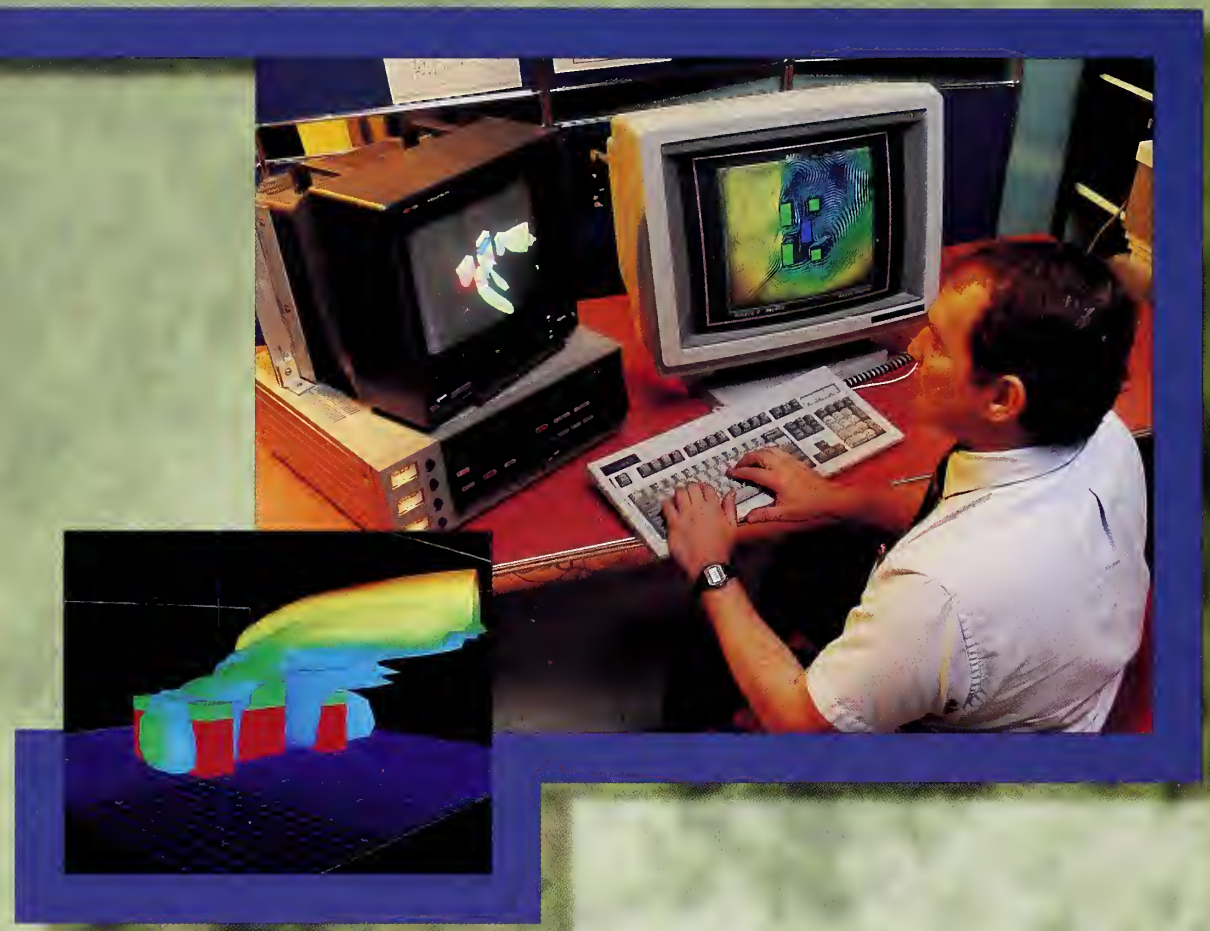
A review of models to be used in the analysis of the transport and diffusion of toxic substances at high altitudes revealed that available models could not support the task. The primary deficiency was in the knowledge and treatment of the high-altitude forces driving these dispersion mechanisms. A suitable model was developed and initially tested in the first of a series of Army Space and Strategic Defense Command validation field trials conducted at White Sands Missile Range, NM.

IMPACT: Once validated, the model developed in this program will provide the Army with a single source for high-altitude and boundary-layer predictions of the hazards associated with the release of both biological and chemical agents. The model will lead to future development of Tactical Decision Aids for predicting effects of hazardous material releases.

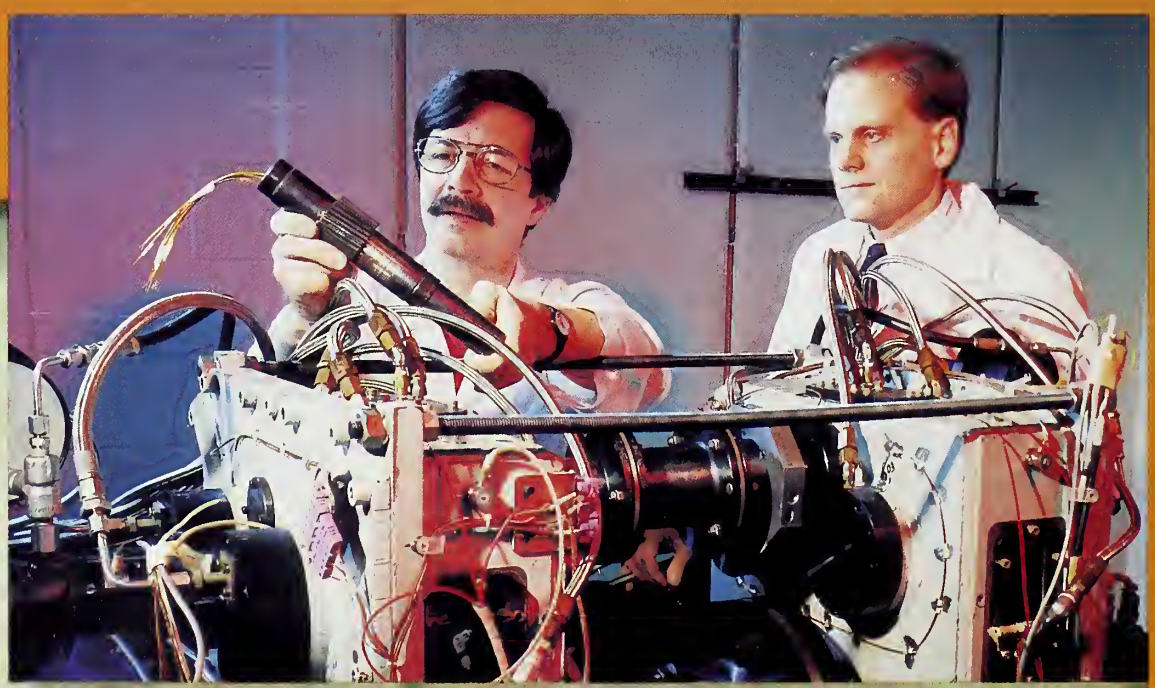
Low-cost, high-energy, rechargeable batteries are critical to the Army's training needs. The picture at left shows the materials used to produce metallic-lithium/nickel oxide rechargeable batteries that provide nearly the energy content of throw-away batteries at a fraction of their cost.

Optical turbulence simulators based on hybrid optical/digital processing techniques offer a cost-effective, efficient, and accurate method of accomplishing dynamic simulation of atmospheric effects. Optical turbulence simulators enhance both combat system and training device development.





Atmospheric transport and diffusion modeling (as depicted left) allows highly toxic nuclear, biological, and chemical hazards to be visualized and predicted over complex terrain and urban structures. Advanced numerical methods and highly parallel computers will allow ARL to solve the governing physical equations and depict three-dimensional downwind hazard zones.



Through advanced finite-element analysis of planetary gear systems, ARL scientists have advanced the state of the art in detailed analysis of loads, displacements, strains, and stresses associated with internal and external spur gears and planetary gear systems. Split torque transmission component test rigs aid in verification of the accuracy of advanced models.

Scene Visualization

The newly developed Battlefield Emission and Multiple Scattering model is a first-principles computer model that provides physically correct atmospheric scene visualization of battlefield smoke and dust. Analytic methods for computing radiative transfer have existed only for simple cloud geometries, uniform concentrations, and uniform illumination along one or more directions. The new model predicts the transmission and radiance fields produced by finite, inhomogeneous aerosol clouds by computing radiant interactions along 26 directions on a regular three-dimensional cubic lattice. This allows for realistic visualization of clouds both in brightness and local spatial variation at wavelengths of user choosing.

IMPACT: The Battlefield Emission and Multiple Scattering model provides the capability to produce and examine realistic clouds for target-acquisition scenarios. It can be used for the development of new obscurants, as the basis for scene generation at various wavelengths, and as a way to obtain statistics on the radiative processes in clouds. This is important for wargamers, trainers, system designers, and simulators, allowing determination of sensor effectiveness and improved training capability.

Vehicle Propulsion

"The Vehicle Propulsion Directorate enjoys access to world-class facilities and expertise at NASA-Lewis, which are necessary to conduct research in support of aviation and ground vehicle propulsion requirements. The technical objectives that drive our mission are all focused on providing the Army with efficient, compact, lightweight, durable, and affordable engines and power transfer systems to support future aircraft and vehicles, as well as upgrades to fielded ones."

Dr. Robert Bill
DIRECTORATE EXECUTIVE

(216) 433-3703

Flow Physics of Centrifugal Compressors

An experimental and computational investigation of the flow field in the NASA Low-Speed Centrifugal Compressor facility was conducted using laser anemometry and Dawes' three-dimensional viscous code. Measurements of the three-dimensional velocity field were acquired at several measurement planes through the compressor. The measurements described both the throughflow and secondary velocity field along each measurement plane. The results clearly documented the development of the throughflow velocity wake characteristic of unshrouded centrifugal compressors. Knowledge gained is essential to meet a DoD goal of doubling turbine engine propulsion capability. The paper describing this work received the NASA-Lewis Paper of the Year award.

Impact: This work provides the basic flow physics knowledge base that will permit the design of centrifugal compressors with better aerodynamic performance.

Finite-Element Analysis of Planetary Gear Systems

Typically, finite-element analysis of gear systems has been done with fixed boundary conditions and point loads on gear teeth or gear sectors. However, the assumptions and approximations used to develop these boundary conditions and point loads have limited the accuracy and application of such analysis. ARL scientists applied the finite-element method to the study of planetary gear systems. This research has produced a method for detailed analysis of the loads, displacements, strains, and stresses associated with internal and external spur gears and planetary gear systems. The newly developed gear analysis method uses nonlinear finite-element analysis with automated contact and treats all gears as deformable elastic bodies mounted on flexible supports. As a result, the state of the art has been advanced in finite-element analysis of gears, because the new method avoids the limitations of previous procedures in such areas as optimizing gear root/fillet geometry, evaluating gear support methods, studying torque sharing/splitting concepts, and studying loaded three-dimensional contacts of helical, bevel, and spiral bevel gears.

Impact: The development of this powerful new tool for analyzing gear system performance will result in smaller, lighter, and less expensive engines and transmissions.

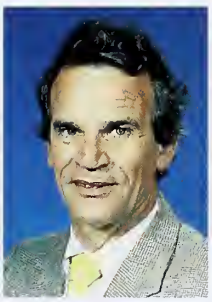
Advanced, Multistage, Small Axial Compressor

Under a joint agreement among Allison Gas Turbines, NASA-Lewis, and ARL, an advanced, multistage, small axial compressor was designed, built, and tested. Conventional codes can analyze only a single blade row at a time and thus cannot account for the important interactions that occur between

multistage blade rows, greatly affecting the performance of multistage compressors. In contrast, the latest code can analyze multistage turbomachinery in a true multistage computational domain and thus is expected to predict performance more accurately. Allison fabricated the compressor hardware, while NASA and ARL instrumented the hardware and modified an existing test rig to conduct the performance testing. The compressor has been tested over its full speed range, and initial results show that it operates close to its design mass flow and overall pressure ratio. The advanced, multistage, small axial compressor uses only two stages to produce a pressure ratio that requires five axial stages with today's technology. Lessons learned during the development of this compressor are expected to be incorporated into the next Joint Turbine Advanced Gas Generator Demonstrator.

Impact: Demonstration of these technologies is essential to meeting the DoD technology goal of doubling turbine engine propulsion capability.

Vehicle Structures



"Our primary competencies at the Vehicle Structures Directorate are in research for structural integrity, crashworthiness, inspection technology, structural dynamics, vibrations, structural acoustics, and aeroelasticity. We see our mission predominantly as developing desired new technologies and actively transferring these to the systems RDECs and their prime contractors."

Dr. Wolf Elber
DIRECTORATE EXECUTIVE

(804) 864-3949

New Textile Technology

Fabrication and design technology for composite structures has been significantly advanced through the development of new textile technology. It is now possible to weave single-layer fabric to net shape; fiber orientations can be optimized with no fiber crimp. The manufacturing cost of these highly tailored materials is substantially less than that of other textiles. A high degree of automation and production quality control is inherent in the weaving process. The continuous nature of this material lends itself to highly automatable processes such as pultrusion and continuous compression molding; these offer additional opportunities for reducing the fabrication cost of primary composite structures. The U.S. Patent Office has issued two patents on this technology.

IMPACT: This technology will have a significant impact on both military and commercial use of composite materials. It is immediately applicable to a range of industries: sports, structural, marine, and automotive.

Fuel Tank Crashworthiness

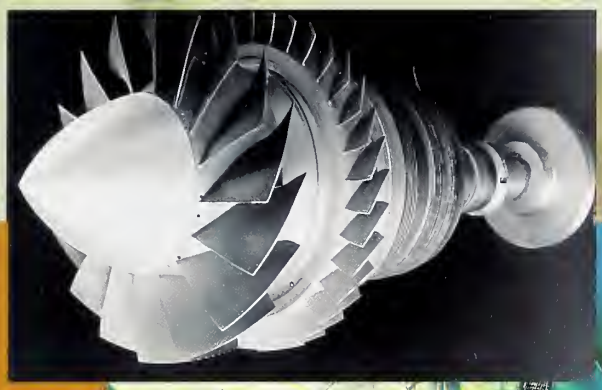
A cooperative research agreement with McDonnell-Douglas Helicopter Co. (MDHC) involved determining the crash-generated internal pressure in fuel bladders that have been encased in energy-absorbing materials. For conducting these tests, MDHC provided fuel bladders constructed of materials that are used for civil helicopters, as well as a bladder container. Five tests were conducted at NASA-Langley, with different combinations of cushioning and crushable material, where internal pressures and accelerations were measured. Findings suggest that materials under the bladder are more effective than materials on the side walls.

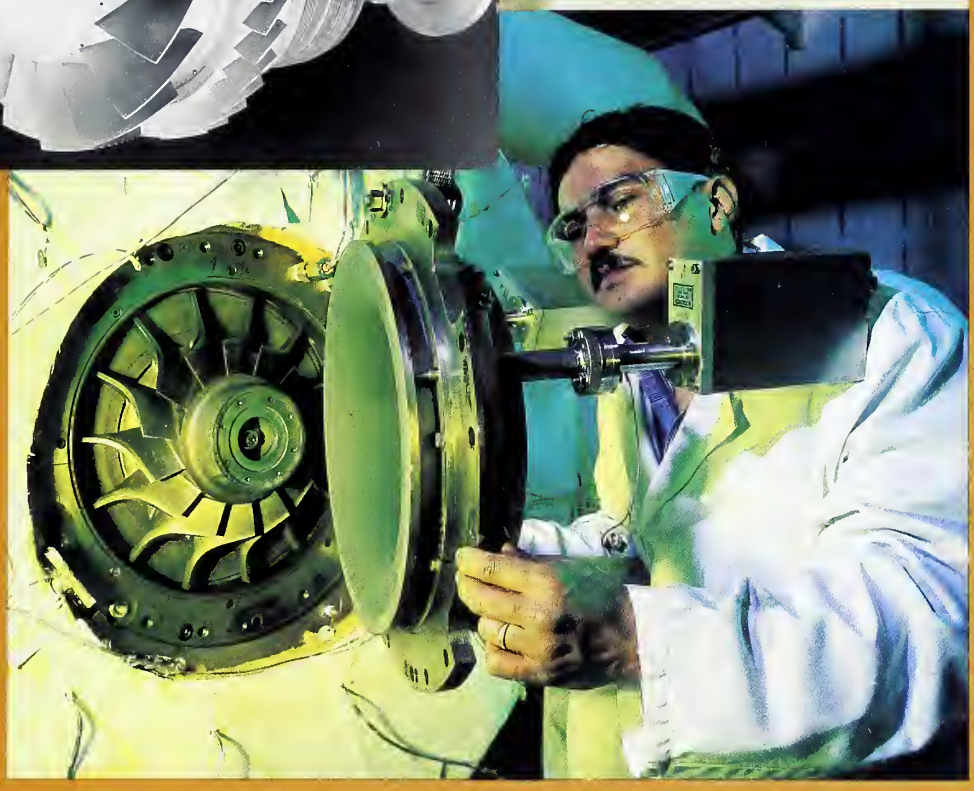
IMPACT: These tests will help in the development of crash-resistant fuel systems for rotorcraft. The instrument and film data from these tests will assist MDHC in developing its new commercial (8-place) "MD Explorer" helicopter and meeting FAA crashworthiness criteria.

Advanced Rotor Blade Technology

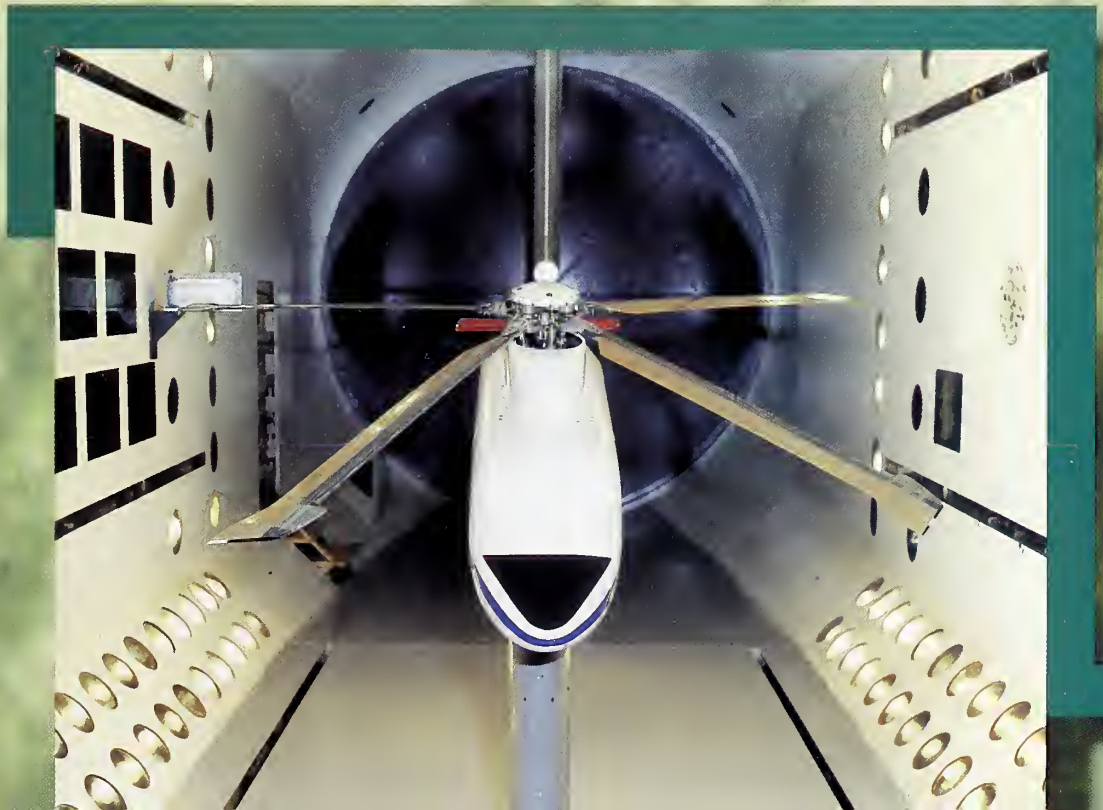
A model test has been conducted in the NASA Langley Transonic Dynamics Tunnel to evaluate rotor blades similar in planform to the British Experimental Rotor Program (BERP) rotor blades. The performance improvements claimed for the BERP planform were evaluated by cross-plotting of data for a rotor representative of the Army UH-60 Black Hawk helicopter. The results indicated that compared to a baseline rectangular planform, the BERP provides increased speed for a fixed rotor thrust and increased load factor capability at a constant speed. Other data from a previous test indicate that a Langley-designed Growth Black Hawk tapered blade planform provides performance improvement over the BERP planform in terms of power requirements and lifting capability.

IMPACT: Validation of advanced rotor blade planform effects will benefit the U.S. helicopter industry in the development of advanced design tools and more maneuverable helicopters.





An ARL scientist is shown instrumenting an advanced, multistage, small axial compressor designed, built, and tested under a joint agreement among Allison Gas Turbines, NASA-Lewis, and ARL. The newly designed compressor uses only two stages to produce a pressure ratio that requires five axial stages with today's technology.



The Langley Transonic Dynamics Tunnel, a model test facility, is being used by ARL scientists and engineers to evaluate and validate experimental helicopter rotor blade designs. Validation of advanced rotor blade planform effects will aid in the development of advanced rotor design tools for more efficient and maneuverable helicopters.

An ARL scientist takes measurements during an active control of sound transmission experiment. The Army/NASA active interior noise-control program seeks to apply active structural acoustic control to reduce airborne interior noise.

Enhanced ballistic performance of ceramics against long-rod kinetic-energy projectiles is of paramount importance to armor developers. Pictured left is a surrogate ceramic material used in the development of ceramic-laminate armors that promise greater effectiveness in defeating long-rod kinetic-energy threats.

Active Control of Sound Transmission

The reduction of aircraft interior noise is increasing in importance to passengers and crew because of increased public awareness of the potential for hearing loss and the fatigue and discomfort created by a high-noise environment. Traditional passive noise-reduction techniques defeat the purpose of lightweight materials by requiring additional mass. Active noise-control techniques can be tailored to reduce discrete noise with a minimum weight penalty. The Army/NASA active interior noise-control program seeks to apply active structural acoustic control to reduce airborne interior noise. This procedure was successfully demonstrated with piezoelectric actuators attached to a graphite composite fuselage model.

IMPACT: Active noise-control transmission mounts are currently being developed by helicopter manufacturers that use this technology to significantly reduce helicopter structure-borne noise.

Weapons Technology

"My vision is that the Weapons Technology Directorate be recognized as the world leader in weapons-related technologies, as we continue to be essential to the Army for our timely accomplishments. WTD has a challenging and rewarding work environment for all, with many opportunities for self-actualization. WTD is well-founded in science and has a 'heads-on/ hands-on' mentality."

Dr. John Frasier
DIRECTORATE EXECUTIVE

(410) 278-6244

Laser Ignites Artillery Charges

A laser ignition system has been successfully used to ignite both conventional bag charges and Unicharge configurations from zones 2 through 8. These tests were conducted at temperatures of –40°F, ambient, and +140°F. The interior ballistic performance was excellent. A laser has been selected as the primary igniter for the 52-caliber Solid Propellant Armaments System, which uses the Unicharge. A laser-based igniter is also being actively developed for the Advanced Field Artillery System Regenerative Liquid Propellant Gun.

IMPACT: Laser ignition technology shows great promise in improving gun performance reliability and reducing system vulnerability.

Enhanced Ballistic Performance of Ceramics

Experimental ceramic-laminate armors have exhibited poor ballistic performance against long-rod kinetic-energy projectiles. By suppressing damage to the ceramic and providing an armor layer that accommodates failed projectile material in a controlled manner, the new armors routinely defeat laboratory-scale long-rod projectiles at the ceramic surface.

IMPACT: This investigation provides armor developers with fundamental information needed to engineer ceramic-laminate armor with greater effectiveness against long-rod kinetic-energy threats.

Round Discrimination System

A Round Discrimination System for use on training ranges was developed that can identify a projectile's caliber and type as it travels toward the target. The proof-of-principle prototype system was demonstrated, and it correctly identified 90 percent of the projectiles fired. The system captures the acoustic shock wave, analyzes its acoustic content, predicts the round type, and sends the round type, hit location, and velocity to a monitor in the range control tower, all in real time.

IMPACT: The Round Discrimination System improves the quality of soldier training with more realistic training scenarios during Tank Tables and Combined Arms Live Fire Exercises. The system also provides an accurate after-action evaluation of the trainees' ability to choose the proper ammunition for the mission at hand.

Spall/Radiation Protective Liner Study

ARL led a team effort with Oak Ridge National Laboratory and the U.S. Army Combat Systems Test Activity to evaluate over 250 material sets to find the optimum armor/hull/interior-liner combination that combines light weight, superior spall fragment suppression, and a high radiation protection factor to enhance crew survivability in the proposed Advanced Field Artillery System.

IMPACT: This study supported PM-System Survivability and PM-AFAS in the demonstration and validation phase of the Advanced Field Artillery System program in enhancing crew survivability.

Theater Missile Defense Lethality

In support of the Patriot system, ARL chaired a committee to review penetration algorithms being used in end-game simulations for the PAC-3 (Patriot Advanced Capability) missile. Upgraded diagnostic instrumentation was used to evaluate rod penetrators versus chemical submunition targets, so that the influence of penetrator geometry, material, and yaw could be assessed. Other experimental programs investigated the performance of Patriot warhead fragments, yielding an improved understanding of fragment response to high-obliquity impact. Complementary hydrocode simulations performed on the CRAY-2 computer provided additional insight into penetration phenomenology for rods and fragments and for hit-to-kill warheads. The combined experimental, analytic, and computational program is leading to an improved understanding of critical lethality issues and requirements for Theater Missile Defense.

IMPACT: By increasing our involvement in Theater Missile Defense lethality, we leverage a significant DoD investment in expertise and facilities. The results that we have delivered to the Theater Missile Defense community have directly supported the development of lethality criteria for Theater Missile Defense and the current PAC-3 decision process.

Materials

"The advanced lightweight durable materials currently being researched at the Materials Directorate are key to the Army's successful transformation into a strategically mobile and tactically deployable force capable of rapid interjection, quick execution, and timely extraction anywhere in the world."

Lawrence Johnson
DIRECTORATE EXECUTIVE

(617) 923-5275

Matched Metal Net Molding Fabrication of Organic Matrix Composites for Ground-Based Interceptor Structures

In conjunction with SPARTA, Inc., ARL is developing technology to fabricate endoatmospheric interceptor structures of higher temperature organic matrix composites that are lighter in weight and lower in cost than those made by the conventional composite fabrication processes. Advanced structures are molded in one piece in a single operation, offering a 30- to 50-percent weight savings at half the cost. An ultra-high-modulus graphite fiber is used in a cyanate ester thermoset matrix.

IMPACT: Using organic matrix composites for interceptor structures will lead to lighter, cheaper devices.

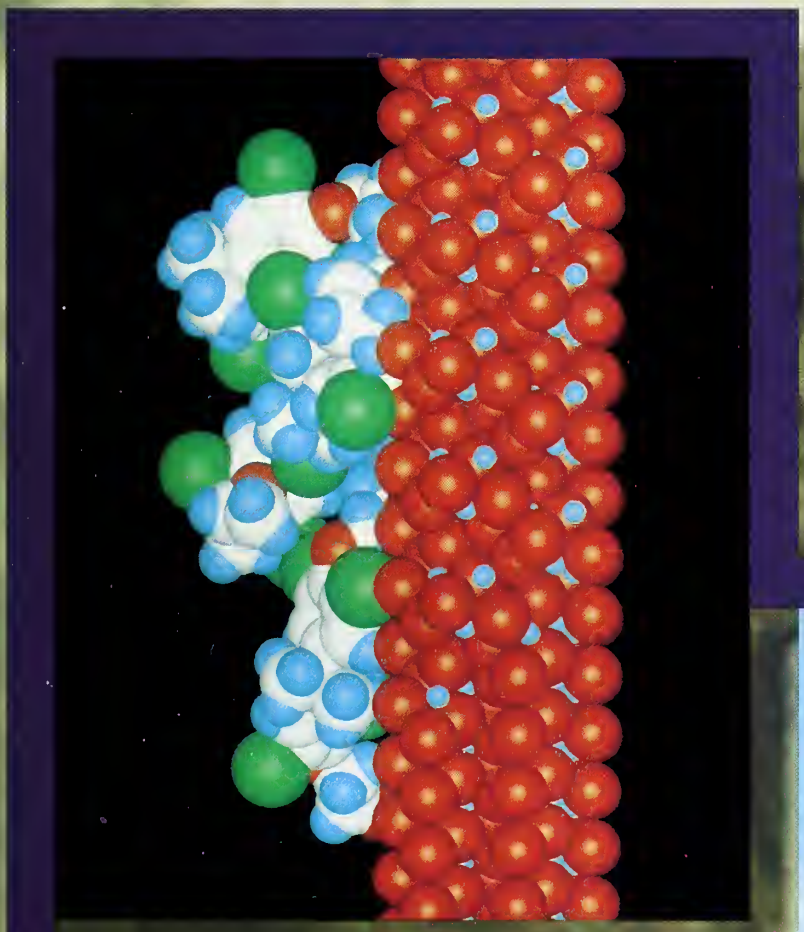
Smart Weave: Sensor Integration for Intelligent Control of Resin Transfer Molding Processes

The Army has identified composites as the material of choice for at least two current/future major weapon system programs: the Comanche attack helicopter and the Composites Armored Vehicle. Resin transfer molding (RTM) processes are likely to be used in the fabrication of parts for these systems.

A necessity of the RTM process, particularly for thick and/or complex shapes, is achieving a complete wet-out of the preform by the injected resin. The existence of dry spots within the molded parts will render them useless. To circumvent this problem, we have developed and patented a prototype sensing system, Smart Weave, for monitoring the resin flow. Sensors, consisting of series of fibers woven in a designed layout, provide information on resin location, flow front velocity, and acceleration. After wet-out, the sensing grid can provide an estimate of fundamental variations in the rheological behavior of the resin as it cures. Such information can also be used to validate and improve simulation models of resin flow, helping to optimize preform and mold design.

IMPACT: Besides its use for optimizing resin transfer molding manufacturing, the Smart Weave process also holds promise for health monitoring of fielded composite components. Experiments are beginning to determine the potential for using the same sensory grid as a quasi-strain-gauge for locating and determining the amount of integral damage to the part. There is also some excitement about the potential use of the grid for active countermeasures against detection by radar signals.

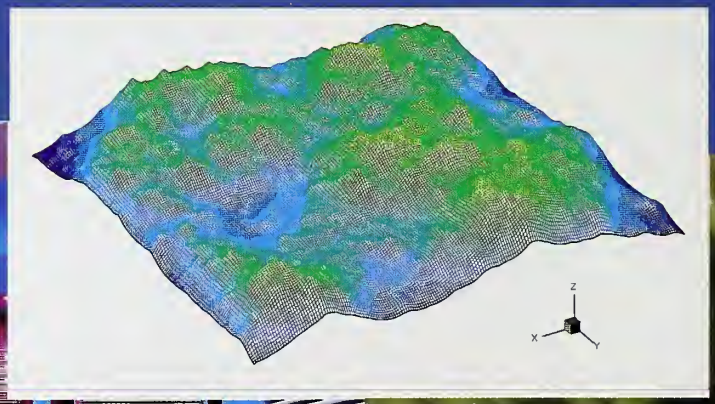
Hydrocode simulations performed on the CRAY-2 computer (pictured left) provide insight and improved understanding of high-obliquity rod and fragment impact and penetration response for hit-to-kill missile warheads. The combined experimental, analytic, and computational program is leading to an improved understanding of critical lethality issues and requirements for theater missile defense.



Computer-assisted molecular modeling has been gaining importance in recent years as a method of predicting the properties of compounds or materials before their synthesis. The long-term objective is to develop models of adhesive joints comprehensive enough to permit not only the design of the joints, but also the prediction of their performance throughout their service lives.

The Matched Metal Net Molding manufacturing process was developed as a cost-effective process for the manufacture of advanced composite structural components. Complex structures are produced without the need for autoclaves by this closed-mold fabrication technique.

In direct support of U.S. Army European Command, ARL developed a model to optimally design flexible, multipurpose protective ballistic blankets (pictured) for protecting troops and equipment. The accuracy of the model was verified through full-scale live-fire ballistic testing of prototype protective covers.



ARL has the mission of developing advanced physical modeling technology to support the design and development of Army weapon systems. Emphasis is placed on adapting existing predictive technology to efficiently use massively parallel processors such as the KSR-1 pictured. Physical models being developed include fluid dynamics, structural mechanics, solid and liquid combustion, electromagnetics, thermodynamics, and geotypical dynamic terrain (inset).

Development of Protective Ballistic Cover

Typical battlefield scenarios result in exposure of combat troops, support personnel, ammunition, and equipment to enemy fragmentation munitions. With support from the Marine Corps, we initiated a program to develop optimal protective ballistic covers, concentrating on fabric armor materials because of their inherent flexibility and multifunctionality. A comprehensive mathematical model was developed that predicts for each material the number of plies required to defeat a fragment mass impacting at a specific velocity. The accuracy of the model was verified through full-scale live-fire ballistic testing of prototype protective covers versus the U.S. 155-mm high-explosive shell (simulant for the Soviet 152-mm HE) at Aberdeen Proving Ground, MD.

IMPACT: State-of-the-art ballistic protective covers that provide excellent ballistic performance at a reasonable cost will reduce personnel wounding and collateral damage.

Advanced Computational and Information Sciences

"The Advanced Computational and Information Sciences Directorate is a growing venture for ARL, designed to foster new and advanced technologies in the fields of computing, simulation, and information. ACIS provides leadership within ARL, the Army, and DoD in the key technology areas of computing, networking, software, simulation, and automation."

William Mermagen, Sr.
DIRECTORATE EXECUTIVE

(410) 278-6639

Basic Research in Channel and Networking Algorithms

In collaboration with the Johns Hopkins University, we made significant progress into methods for decreasing delays in battlefield computer nets by greatly reducing the need for packet retransmission. We have developed new error control coding techniques, permitting a fixed number of stations to share a communications channel—in effect "colliding" with one another—while enabling each receiver to decode its own message without error.

IMPACT: Tactical command and control operations can be enhanced by the elimination or significant reduction in the number of messages that must be retransmitted. New protocols will significantly decrease delays in receipt of important combat information. Of equal importance is the associated decrease in the time that a radio transmitter must be on the air, reducing the likelihood of enemy detection of troops.

Parallel and Distributed Computation of Geotypical Dynamic Terrain

At the highest resolutions available, Defense Mapping Agency terrain data lack the detail and dynamics required by combat models and simulators for the land warrior. This significantly reduces the realism and overall effectiveness of training, and improves the accuracy of combat materiel assessments. For the dynamic nature of the battlefield to be fully reflected during a real-time combat simulation, the terrain must be computed at high resolution with near-real-time updates of terrain changes. Computer generation of geotypical high-resolution dynamic terrain is ideally suited to massively parallel computers and the distributed approach for real-time combat simulations. ARL's Variable Resolution Terrain model has been implemented on massively parallel computers in a client-server distributed computing system. The ARL Variable Resolution Terrain model can be used to generate high-fidelity geotypical dynamic terrain for combat simulations.

IMPACT: The ARL Variable Resolution Terrain model will be compliant with the Distributed Interactive Simulation standard and will be available to simulations requiring high-resolution dynamic terrain.

High-Performance Computing Modernization Program

ARL has helped shape, manage, and implement the DoD High-Performance Computing Modernization Program, including project coordination for the Interim Defense Research and Engineering Network. ARL will be the agent for the mature system component of the program. In addition, DoD modernization includes advancing the integrating technology of high-speed networking. During FY93, the network grew to service 50 sites across DoD, with a backbone of dual T1 (1.5 Mbps) connectivity. ARL staff has been instrumental in formulating the vision for the follow-on Defense Research and Engineering Network capability, projected to reach the gigabit and beyond.

IMPACT: Modernizing high-performance computing hardware and architectures will lead to significant increases in computing power and availability within DoD.

Manufacturing Simulation for Resin Transfer Molding Processes

ARL developed a design simulation tool, to be run on high-performance computers, for resin transfer molding manufacturing of large, complex carbon-epoxy composite components, such as the RAH-66 Comanche keel beam.

Current manufacturing techniques are high-risk, high-rate-of-failure, and high-cost processes that do not take advantage of computer simulation tools to design part molds. This simulation tool uses finite-element calculations to simulate the resin flow fronts into the carbon fiber preform, the transient temperature fields of the keel beam, and the cure kinetics of the resin. The tradeoffs of injector and vent placement, surface geometry of the part, and the resin/preform interactions are clearly demonstrated.

IMPACT: Perfecting the simulation tool will allow the production of large, complex, low-cost, high-reliability composite components for Army systems such as the Comanche keel beam and thick composite armor panels.

Human Resources and Engineering

"The goal of human research and engineering is to define human performance in the perceptual, cognitive, and psychomotor domains, so that the modern Army can maximize the usefulness of its most important asset, the soldier."

Dr. Robin Keesee
DIRECTORATE EXECUTIVE

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Lower Extremities Assistance for Parachutists Program

Landing injuries are a significant problem for airborne troops: estimates are that 2 to 6 percent of the troops are injured during combat drops. To support the Special Operations Forces, we conducted experiments to examine the biomechanics involved in a parachute landing fall, to find a means of significantly reducing the impact forces transmitted through the body, and to develop a prototype for Special Operations Forces to test during actual parachute jumps. The results of this program are being used to provide an integrated lower extremity supportive/enhancement and protective device.

IMPACT: Lower Extremities Assistance for Parachutists devices will improve the safety and effectiveness of airborne troops. Such devices are also of interest to the U.S. Forest Service, which has similar requirements and problems for smoke jumpers.

CoVRT—Commander's Visualization Research Tool

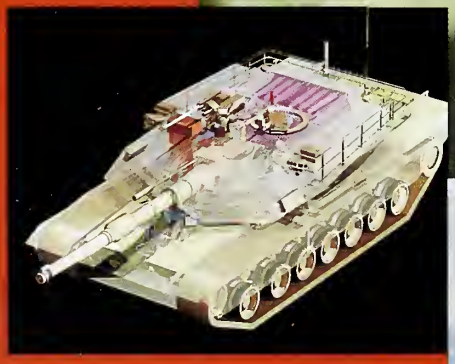
Working with the U.S. Army Intelligence Center and the Communications-Electronics Command (CECOM), we developed CoVRT, a prototype information system to display real-time intelligence sources to the brigade commander. The CoVRT prototype allows us to investigate information management and cognitive representation principles that will give the commander intuitively formatted, time-sensitive battlefield information. FY93 research culminated with a demonstration of CoVRT presenting real-time and near-real-time multisource intelligence to a surrogate brigade commander using actual sensor information from a National Training Center exercise. CoVRT software is designed to be maximally flexible, allowing the commander to set his own information priorities.

IMPACT: Potential benefits include improvements in battlefield synchronization through shared visualization display techniques, faster decision cycles for maneuver commanders, and the new capability of displaying to the commander "on the move" instantaneous changes in the enemy situation. CoVRT is already influencing the course of CECOM's Advanced Technology Demonstration for the common ground station.

The RAH-66 Comanche helicopter design calls for a carbon-epoxy composite keel beam. The primary structural component will be 24 ft long. Making this part as one piece by resin transfer molding presents a difficult technical challenge. The ARL developed design simulation tool will greatly reduce this challenge and make large, complex composite components affordable and more reliable.

In direct support to the Special Operations Forces, ARL conducted experiments to study, design, and prototype a protective device to reduce the number of injuries incurred during combat parachute drops. Results of this effort are being used to provide integrated lower extremity supportive/enhancement and protective devices to Special Operations Forces.

The Auditory Detection Model developed by ARL is a powerful tool that predicts the detectability of sound by unaided human hearing. The main applications of the model are for understanding the detection phenomena for different listening conditions, for guiding the noise-reduction design of materiel, and for establishing noise standards.



ARL makes use of a variety of state-of-the-art models and facilities to simulate warfare environments so that developmental systems and components can be analyzed for their ability to survive threats. The photo right illustrates the Electro-Optical Data Acquisition and Tracking System (EODATS), a van-mounted test facility that enables the measurement of effects of emulated electro-optical countermeasures during field experiments. The Stochastic Quantitative Analysis of System Hierarchies (SQuASH) probabilistic computer model (shown left) was developed to provide vulnerability estimates of armored vehicles impacted by various munitions. The model uses high-fidelity three-dimensional target geometry, including armor packages, interior components, and personnel.

Auditory Detection Program

We have developed an Auditory Detection Model for predicting the detectability of personnel and equipment by unaided human hearing. The computational process of the auditory detection model may be separated into two broad categories: sound propagation losses and psycho-acoustic factors. To date, a number of validation studies have been conducted at distances under 1000 m, indicating that the actual detection distances of human listeners agree with the computations of the model.

IMPACT: This model will enhance soldier and system survivability by efficiently reducing detectability of materiel, and will improve the understanding of sound propagation and auditory detection.

Survivability/ Lethality Analysis

Survivability/Lethality Analysis

We analyze the survivability/lethality (SL) of Army systems against the full spectrum of battlefield threats: ballistic threats; chemical, biological, and nuclear effects; and electronic warfare components. The technologies of these threats are different, but their use affects in various ways how an Army system performs in battle. The thrust of the survivability/lethality analysis (SLA) effort is to identify the effects of these threat components and integrate the results so that we can project the performance of systems under acquisition. To this end, we conduct the necessary investigations, simulations, lab/field experiments, and analysis to quantify the SL of Army systems. We provide technical advice and consultation on SL matters to decision makers, Project Managers/Program Executive Officers, users, testers, independent evaluators, and other customers. Assessment support is provided to numerous Army PMs and RDECs, as well as other DoD agencies.

"The Survivability/Lethality Analysis Directorate is the only ARL directorate that has analysis as its principal function. SLAD's main reason for being is the integration of the survivability/lethality analysis processes within the Army into one synergistic and coordinated effort. To accomplish this, SLAD has been structured to combine the Army's primary analytical expertise in the disciplines of conventional ballistics, electronic warfare, directed energy, nuclear energy, and biological and chemical warfare into one coherent operation."

Dr. James Wade
DIRECTORATE EXECUTIVE

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Full-spectrum SLA programs were conducted on 36 high-priority Army systems, including the Comanche helicopter, the Patriot missile system, the Advanced Field Artillery System, and the Javelin antitank missile. Major SLA support was also provided to the Ballistic Missile Defense Organization and the Live-Fire Test Program.

IMPACT: As a result of these SLAs, significant contributions were made toward enhancing the survivability and lethality of numerous Army systems against the full spectrum of battlefield threats.

Modular Unix-Based Vulnerability Estimation Suite

We upgraded the Modular Unix-Based Vulnerability Estimation Suite (MUVES) to implement a prototype spall-generating module for kinetic-energy and space-charge threats for all armor. The MUVES is a computer applications package that encompasses a coherent hierarchy of ballistic vulnerability/lethality models addressing the full spectrum of ballistic vulnerability analysis needs.

IMPACT: The Modular Unix-Based Vulnerability Estimation Suite upgrade increased precision in integrating vulnerability reduction and lethality improvement measures.

Databases

Three SLA databases were supported this year: AMC's Nuclear Survivability Status Tracking Systems, the Chemical Defense Materials database, and a commercial solvent database. The Nuclear Survivability Status Tracking System was reviewed as a possible data source for Army-wide simulations. Fifty materials were screened for chemical resistance, and the results entered into the chemical defense database. Additionally, seven ASTM (American Society for Testing and Materials) test standards for surety chemicals against materials were established and entered into the database. We developed productive techniques to assess the effects of agents and decontaminants using a commercial solvent database.

IMPACT: The impact of this work is twofold. First, the Army-wide simulation program is being undergirded with solid data to support simulation validity. Second, the chemical databases will not only make contributions to military systems design and evaluation, but also have broad commercial utility.

Support Initiatives and Highlights

Dramatic changes in the post–Cold War world order and massive reductions in the U.S. defense budget present enormous challenges to the Army scientific and technical (S&T) community. Not the least of these is to be responsive to our customers and to operate in a more businesslike fashion. Finding ways to absorb financial and personnel reductions while shaping a better future is no easy job, but ARL is succeeding.

Advanced Concepts and Plans

"The Advanced Concepts and Plans Directorate personnel provide a vital link between the bench technologists, their managers, and the whole spectrum of ARL customers, users, higher HQ staff, and political interests. As ARL begins operation as a pilot project under the Government Performance and Results Act of 1993, ACAP will play a critical role in achieving management flexibility in exchange for management accountability and in moving ARL toward true world-class status."

Bruce Fonoroff
DIRECTORATE EXECUTIVE

(301) 394-4106

Program Planning

ARL Business Planning

ARL has developed a unique three-volume business plan, which is tied to key stages of the Planning, Programming, Budget, and Execution System (PPBES). The foundation of the process is a global assessment of ARL's strengths and weaknesses, in the context of the internal and external environment, and establishment of appropriate thrusts and technology and management initiatives. In January 1993 we published Volume 1, *Global Strategy*, which for the first time documents the environment and direction of ARL. In August 1993 we published Volume 2, *Long-Range Plan for FY94–FY99*, which articulates the technology strategy for the laboratory and allocates resources to each of our major business areas and sub-business areas. It focuses on the processes we have designed to be responsive to our customers and analyzes the economic viability of the laboratory. Volume 3, *Year of Execution Objectives*, published in December 1993, addresses short-range goals and sets measures of effectiveness.

Customer Support

ARL's primary customers are the AMC RDECs, the DA Deputy Chief for Personnel, AMC's Simulation, Training and Instrumentation Command, and the Army Materiel Systems Analysis Activity. Memoranda of Agreements with Technology Program Annexes (TPAs) have been established with these customers to satisfy their needs for technology development and analysis. ARL has 92 TPAs with its 13 primary customers, which identify deliverables, schedules, and resources to satisfy their technology and analysis needs. In FY94, ARL has programmed 58 percent of its basic research and exploratory development mission funds to support these customers.

Army-Wide Strategy

ARL's vital role in support of the Army's S&T strategy is reflected in the Army's Science and Technology Master Plan (ASTMP). ARL provides input to the entire ASTMP and, with support from the Army S&T community, is the proponent for two of seven chapters in the ASTMP: Chapter IV, *Technology Development,* and Chapter VII, *Technology Transfer.* ARL is also responsible for accomplishing 38 of the Army's 200 Science and Technology Objectives. In 1993, ARL's investments in these high-priority research and development programs totaled $33M. ARL is an integral component of the Army's S&T vision and strategy and integrates diverse technologies into coordinated programs to provide essential battlefield capabilities. The process of developing TPAs opens a useful dialogue between ARL and our RDEC customers that helps discipline us in our identification of customer technology needs, as it documents our commitments to ARL customers. Semiannual review of TPAs assures our responsiveness to these customers. ARL is committed to meet its goal of ensuring that at least 50 percent of its 6.1 and 6.2 mission funding supports our primary customers with solid TPAs in the future.

Cooperative Programs

Technical developments that occur outside the Army in-house technology base efforts can often provide technologies that strengthen and improve warfighting capabilities. Where costs can be shared or joint programs established, the Army's R&D investment leverages the non-Army investment.

Academic Collaborations

In addition to industry partnerships, ARL established broad-based collaborations with several academic institutions during FY93, including MIT and the universities of Delaware, Maryland, and Massachusetts, as well as universities in the Southwest, including New Mexico State University, University of Texas-El Paso, University of Arizona, and Colorado State University. ARL-East and ARL-West also maintain vigorous technical outreach programs with segments of the local public sectors, including local public school systems and economic development organizations. ARL added three more Education Partnership Agreements during the year and has transferred over $1M of laboratory equipment to schools for use in mathematics, science, and engineering education.

Small Business Innovative Research (SBIR) Program

The three-phase SBIR program has proven to be a major success for its contributions to defense conversion and dual-use technologies. An example of success obtained from this program is the Phase I award to North Star Research Corporation, which supported work essential to the development of a tube oscillator, an integral component of the Nested High Voltage Tandem Accelerator used for creating particle beams. This technology has several important uses, including the production of medical isotopes for positron emission tomography and the analysis of semiconductors for defects. This invention was selected by *R&D Magazine* as one of the most technologically significant new products of the year for 1993. In FY93, ARL had 53 Phase I and 76 Phase II SBIR contract actions, for a total dollar amount of over $16.4M. Similarly, through careful planning, commercial technology can be "spun-on" to military applications, thus increasing the production base and reducing cost.

International

Consistent international policy, technology assessments, and implementation strategies form the groundwork for a focused, rational approach to international cooperation. The geographical focus was directed toward Australia, Canada, Central Europe, the former Soviet Union, France, Germany, Israel, Japan, Korea, Scandinavia, South America, and the United Kingdom (UK). During FY93, an international robotics investment strategy was developed, and a technology assessment of electric power sources was begun. A summer Engineers and Scientists Exchange Program was initiated with seven ARL scientists and engineers (S&Es) spending 60 to 90 days in labs in France, Germany, and the UK. Key Nunn Programs were started on lithium batteries with France and machine translation with Japan. Technology Working Groups (TWGs) with France, Germany, and Israel all held successful meetings. The Israel TWG completed four technology assessments (ballistics/protection, human research, S3I, and robotics). In addition, an ARL International Program Guidebook was prepared to aid and stimulate ARL S&E participation in international program activities.

The resources of the Army are coupled with those of other countries for joint development of technologies useful both to the Army and to our international partners. The resulting synergy provides the opportunity to achieve goals that might not otherwise be realized.

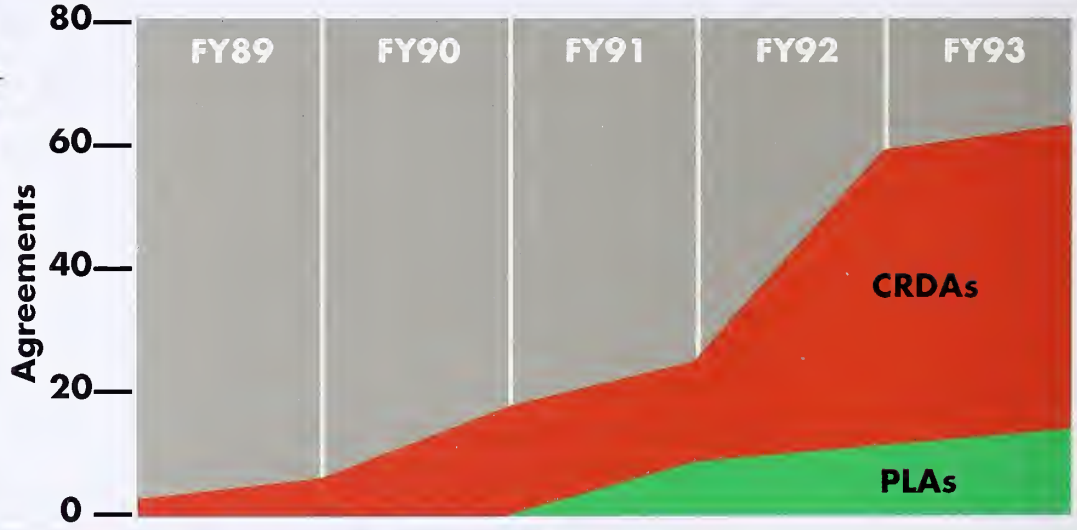
Independent Research and Development (IR&D)

As the manager of the Army-wide IR&D program, ARL acted as Army liaison with industry and DoD on IR&D issues and coordinated and participated in the FY93 review of 20 IR&D programs among the RDECs, Air Force, and Navy. ARL participation in IR&D reviews is a vehicle by which industry R&D efforts can be leveraged. ARL represented the Army on the Joint Directors of Laboratories subpanel on IR&D and worked closely with the industry Multi-Association IR&D Task Group to streamline IR&D reporting guidelines. This effort contributes to a more efficient IR&D reporting process for industry, reduces industry's cost of reporting, and helps focus IR&D reports on ARL technology needs. Through these interactions, ARL can articulate its interests, and the firms can then tailor their future activities more closely to ARL technology needs. ARL gains detailed knowledge of industry technical efforts and can therefore focus its own investments to avoid duplication of R&D efforts.

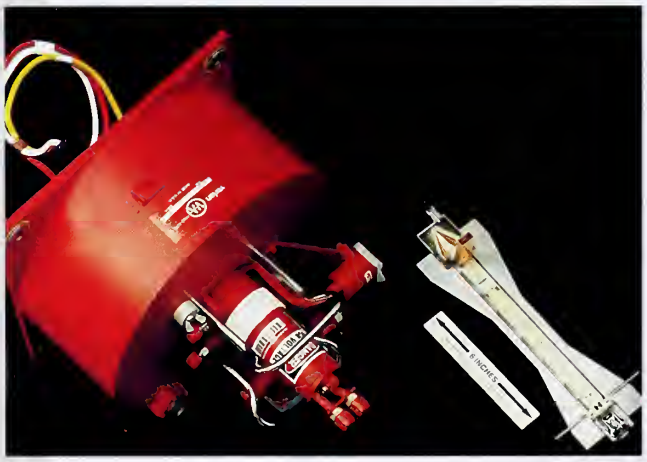
Cooperative Research & Development Agreements (CRDAs) and Patent License Agreements (PLAs)

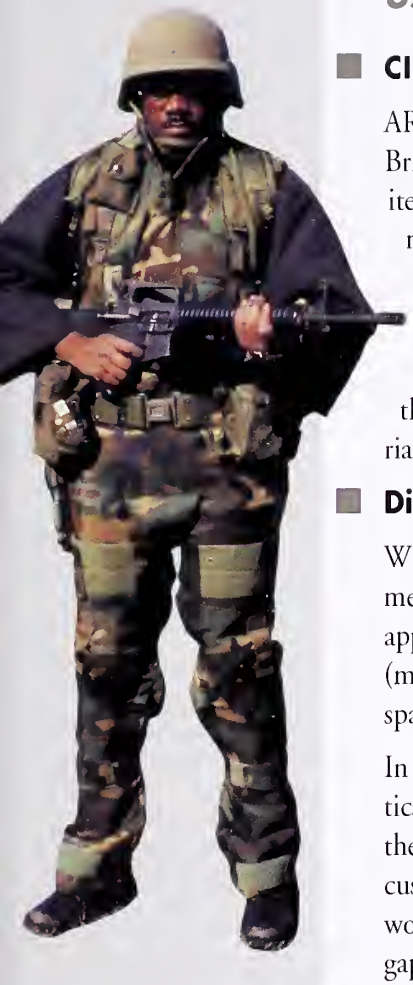
ARL is the DoD leader in CRDAs. Since the passage of the Federal Technology Transfer Act of 1986, ARL has aggressively pursued CRDAs and PLAs as an effective means of transferring dual-use technologies and research results from our laboratory to the private sector. In FY93, ARL entered into 14 new CRDAs and 2 new PLAs. One of the new CRDAs is for an adaptive antenna processor for interference suppression and direction-of-arrival estimates. Other examples of potentially marketable products supported by ARL CRDAs include sporting goods (e.g., new materials for windsurfer masts and hockey sticks), new lightweight printing rollers and shafts, laser-guided imaging for tooling used in fabricating composite structures, and composite wind turbine blades.

State-of-charge indicating devices for high-energy batteries.



Dramatic weight and size reductions in traveling-wave-tube technology.





ARL contributions in the areas of materials selection, design, human factors, and survivability evaluation made additional body armor protection available for soldiers in Somalia.

CINC Support

ARL has been actively working with USAEUR, having established direct links with the Berlin Brigade and the 1st Armored Division in Europe, to aid in potential peacekeeping missions. One item identified as having a high payoff is a family of Kevlar blankets to protect soldiers from fragments. In keeping with ARL's mission of being the Army's corporate laboratory, a marketing team has been formed with the Natick RDE center, to work with the 1st Armored Division to define their needs and to establish an acquisition strategy.

In response to an urgent request from CENTCOM for additional body armor protection in the lower abdomen and extremities for soldiers in Somalia, ARL contributed in the areas of materials selection, design, human factors, and survivability evaluation.

Diagnostics and Prognostics

While ARL has always recognized the importance of identifying and developing technologies to meet the diagnostic and prognostic requirements of systems, recent changes have resulted in a new approach to this area. There will be fewer systems in the future theater of operations, fewer people (military or civilian) to maintain the systems when they break down, and a decreased availability of spares to repair systems in theater.

In order to address the broad maintenance implications, ARL conducted a workshop on diagnostics and prognostics which was attended by OSD policy makers, the TRADOC user community, the AMC RDECs, and ARL technologists. The attendees reviewed the global situation and discussed the emerging technologies that may be applied to diagnostics/prognostics. As a result of the workshop, a study was initiated to identify commercial technologies that are available to bridge the gaps in Army diagnostics/prognostics technologies.

Battle Labs

ARL's close interaction and continuing support to the Battle Labs is a high priority. Conceptual leaps in materiel system capabilities meet the present and future challenges of projecting military power and responding to ill-defined threats with fewer, smaller, deployable units, as well as fully supporting the Army of the twenty-first century. Battle Labs are a catalyst for making these conceptual leaps, providing a means for the Army to systematically examine warfighting ideas and evaluate the options offered by new technical capabilities.

TRADOC is one of our main customers, and it is essential that it be fully aware of ARL's technology developments and capabilities. The Battle Labs introduce advanced and emerging technology to the soldiers early enough so that feedback is provided to system developers on needed improvements from the experiences of soldiers. Based on the feedback from the Battle Labs, ARL has made adjustments in its R&D investment strategy. ARL provided strong support to the Battle Labs during their creation, including placing ARL liaison personnel on-site at the Mounted Warfighting Battle Lab, the Depth and Simultaneous Attack Battle Lab, and the Battle Lab Integration Team. At the Dismounted Soldier Battle Lab, ARL assisted in developing specific solutions to problems such as fuel cells for power generation, Kevlar blankets for protection against fragments, and technologies to locate snipers. ARL also supported the Combat Support Service (CSS) Battle Lab in their development of a technology plan for the Total Distribution Advanced Technology Demonstration (ATD).

Future Joint Warfighting Capabilities

ARL's research and technology development programs are focused on providing the "Technology Edge" in future Joint Warfighting Capabilities (JWCs). ARL's initiatives in battlefield environment technology to "Own the Weather" and in information distribution technology are examples of research in support of a JWC: "to maintain near-perfect real-time knowledge of the enemy and communicate that to all forces in near real-time." Another example is ARL's work in advanced materials research to improve strategic deployability by reducing the weight and volume of combat vehicles; this supports another JWC: "to promptly engage regional forces in decisive combat on a global basis."

Composite hull for heavy combat vehicles.

Composite Hull Technology for Heavy Combat Vehicle Applications

The primary objective of the composite hull program is to reduce armored vehicle weight while maintaining crew and vehicle survivability on the modern battlefield. These objectives are being met by the development and application of polymer composite materials systems in place of current metallic hull construction. Other benefits of the composite hull technology are corrosion resistance, fatigue resistance, lower life-cycle costs, and possible lower manufacturing costs. The experience and data based on thick composites can now be extended to heavier class combat vehicle hulls. A 55-ton vehicle class composite hull was designed and fabricated. Structural evaluations, such as hull racking, side armor loading, and road wheel fatigue testing, were completed.

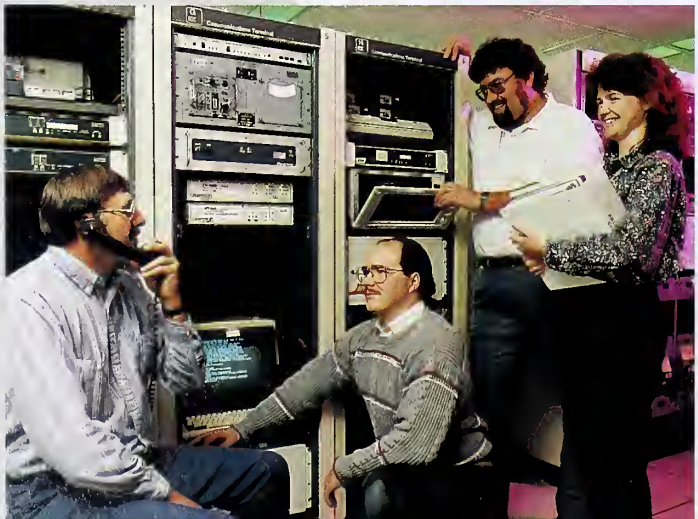
Integrated Meteorological System

Owning the Weather Program

Owning the Weather (OTW) is the use of knowledge of the environment and its effects to gain a decisive advantage over enemy forces through selection of the appropriate mix of battlefield sensors, weapon systems, and tactics that give friendly forces the ability to see, maneuver, fight, and win in all types of weather.

This technology can serve as a combat multiplier by providing commanders and staffs with advance knowledge of battlefield environmental conditions and effects on friendly and enemy systems and operations, enabling them to choose the best time, manner, and place of engagement for quick, decisive victory. OTW allows commanders to fully exploit weather-derived advantages for our systems over hostile systems through the horizontal integration of technology and information systems, including meteorological systems, environmental and communications satellites, automated decision aids, and battlefield displays.

Research in channel and networking algorithms



Information Distribution Technology

ARL's Information Distribution Technology (IDT) research program continues to explore and develop computationally intensive paradigms that exploit the rapidly increasing computer power available to the warrior who may have to contend with a relatively low bandwidth communication environment. Techniques have been developed to automatically adapt information distribution requirements and priorities to dynamic bandwidth capabilities.

The innovative concepts and techniques developed and demonstrated as part of the IDT program have received significant attention and recognition from a wide audience in the command and control (C2) community. Consequently, IDT has helping extend the vision of both C2 users and developers.

Personnel

"The Operations Directorate is driven by three imperatives: reduce expenses; execute the requirements of the Base Realignment & Closure Act; and continually improve customer satisfaction for our value-added services. In FY93 we made great progress in these areas, and I'm extremely proud of our team."

Chuck Denney
DIRECTORATE EXECUTIVE

(301) 394-1001

Equal Opportunity Program

ARL places great emphasis on the value of diversity and made significant strides in representing this diversity in the workforce during FY93: (a) ARL was officially commended by the Equal Employment Opportunity Commission for increasing representation in nine affirmative action categories. (b) A person was assigned to work full-time on the Historically Black Colleges and Universities/Minority Institutions (HBCU/MI) program, resulting in the largest fraction of contracts devoted to HBCU/MIs in the Army and DA endorsement as the best program in the Army. (c) All ARL supervisors received training in EEO and prevention of sexual harassment.

Handicap Program

ARL continues to lead the Army in programs for the handicapped. One employee was the gold winner of the Federal Executive Board's Outstanding Para-Professional Award. ARL also has an extensive outreach employment program. An association with the John Archer School provides part-time employment for 22 handicapped students at Aberdeen Proving Ground. Working with the National Institute for the Severely Handicapped, we have provided full-time employment opportunities at our Adelphi campus.

FAST and FAST-Jr Programs

ARL continued to be the largest supplier in the Army of Science Advisors to active duty field units through the Field Assistance in Science & Technology (FAST) and FAST-Jr programs. In FY93, ARL had five Science Advisors and five FAST-Jr participants working around the world. In FY93, 23 ARL S&Es received 250 hours of training each to prepare them for FAST-Jr assignments.

Long-Term Training

ARL significantly increased long-term training assignments, with 35 scientists and engineers participating in FY93. Two of these were prestigious Secretary of the Army R&D Fellowships. Another participated in the LEGIS Fellows program as a legislative assistant for Senator Barbara Mikulski, handling national defense and foreign affairs issues.

Development Programs

Special recruitment and development programs continued to provide a source of highly qualified employees. ARL had 28 DA interns who completed their training in FY93. A robust Upper Mobility Program has 21 participants.

Restructuring

The restructuring of ARL will be complete in FY97. During FY93, job descriptions were written for every position expected to exist in FY97. These were assessed against the current population so that areas could be identified for hiring, placement, and training. ARL reduced its civilian population from 3909 to 3576 during FY93. To ease the transition, ARL offered early retirement and separation incentives. This resulted in 225 people accepting the offers, thus avoiding a reduction in force.

Over 800 people could potentially relocate under the BRAC during the next four years. To ensure a high relocation percentage, ARL implemented the findings of a study of the psychological aspects of transferred employees. In FY93, 53 percent of the 59 employees offered relocation accepted.

Military Assignments

ARL conducted a zero-based review of all military positions, which resulted in reassignments. The objective was to ensure the effective use of soldiers as communicators of the warfighter's environment—not to employ soldiers in administrative functions.

Facilities

Base Realignment and Closure (BRAC)

Two ARL installations slated for closure under the BRAC 88 and BRAC 91 laws—Watertown, MA, and Woodbridge, VA—have made significant strides in environmental actions necessary for their remediation and reuse. Watertown has been particularly successful in its progress toward the cleanup of its radiological facilities, nuclear reactor, and mixed waste. Decommissioning of the nuclear reactor cost $60M and required 500 contractor personnel working round the clock. At the same time, ARL is working closely with federal and state agencies and the community reuse committee in developing options for the future of these facilities. Under BRAC realignment activities, the first physical relocation of personnel has been accomplished.

ARL implementation and execution of the BRAC requirements has been scrutinized by the following organizations in FY93: Army Audit Agency, Department of Defense Inspector General, Defense Science Board, General Accounting Office, and the National Academy of Sciences. These reviews have generally been positive, and implementation is on track.

Productivity Capital Investment Program (PCIP)

We received $1M in PCIP funding for FY93 and completed postinvestment analyses on 20 previous projects, resulting in documented savings of $9.2M. Since FY86 ARL has received $96M for 150 productivity projects, resulting in validated savings of $110M.

Communications

Information Sharing

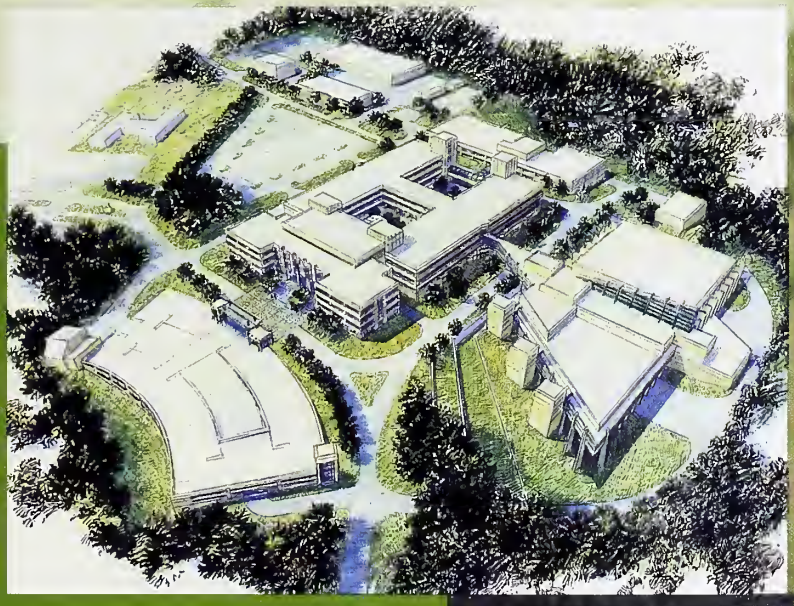
An intensive communications effort was executed to keep the workforce informed of ARL's strategic direction and the current environment. This included numerous small group sessions with the Director, Town Hall meetings, a monthly Transition Events Bulletin, and an ARL-wide ombudsman network.

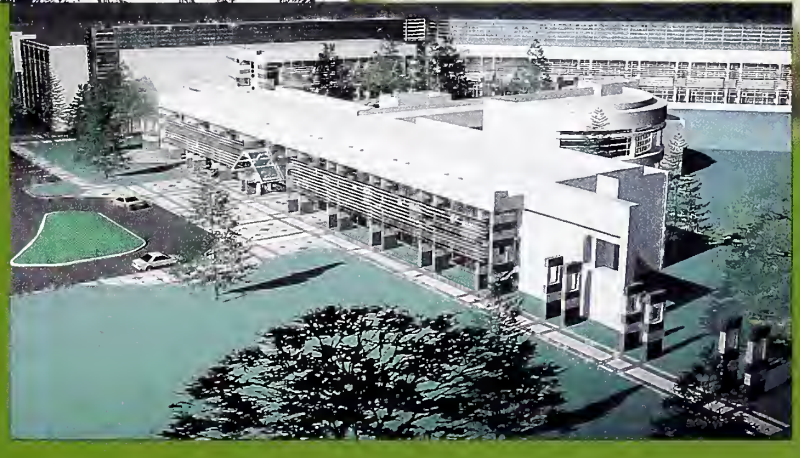
Electronic Commerce

ARL was one of the first government organizations to start exploiting information technology for procurements. Solicitations have been issued electronically, and the response from contractors has been very positive. Preparations are being made for the contractor to be able to respond electronically. This will save weeks in the administrative lead time associated with the procurement process.

Executive Information System

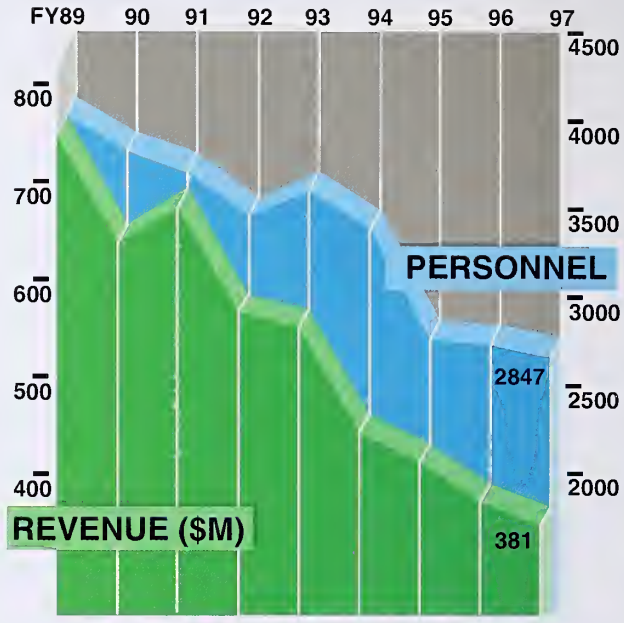
ARL developed an Executive Information System for senior managers, which is available on-line from their desktops. This allows tracking of key metrics, trend analysis, and a "drill down" capability to allow managers to see the data supporting the high-level metrics.





Pictured are artist's concepts of planned new facilities for ARL: (top) the result of new construction and upgrading of Adelphi Laboratory Center to support the Electronics & Power Sources, S3I, and Battlefield Environment Directorates; (bottom) a state-of-the-art materials facility at Aberdeen Proving Ground, scheduled for FY94 construction. Both of these projects, required for compliance with BRAC, continued to progress through the preliminary design phase. Scientists and engineers who will occupy the new facilities actively participated in the laboratory design.

Financial Review



The reshaping of ARL is part of the Army's overall strategic restructuring of its R&D organizations. This restructuring has substantial financial implications. ARL, as originally conceived, was to be mission funded for basic operating costs—labor, benefits, training, travel, equipment, and support contracts—and the customer program limited to 30 percent of the appropriated mission program. The Army's continuing fiscal reductions have been shared with ARL, as shown in the adjacent chart, and institutional funding will not be achieved. ARL's revenue over this period will fall approximately 50 percent and be more focused on basic and applied research. To meet this mandate of improved value to the Army, ARL took positive steps to operate more like a successful commercial business:

Business Plan

The first ARL business plan targeted elements of expense for reduction and included one of the first true management accounting efforts in DoD to delineate an organization's overhead.

Overhead Reduction

A 100-percent review of all ARL processes was conducted. This resulted in a reduction in general and administrative expenses of 8 percent in FY93. These saving were achieved through the use of excellent business practices, reengineered processes, and the elimination of unnecessary work.

Construction Expense Reduction

ARL has $182M in new facilities planned for construction under the restructuring to meet the BRAC law. During FY93, these requirements were refined several times, resulting in a savings of $13M.

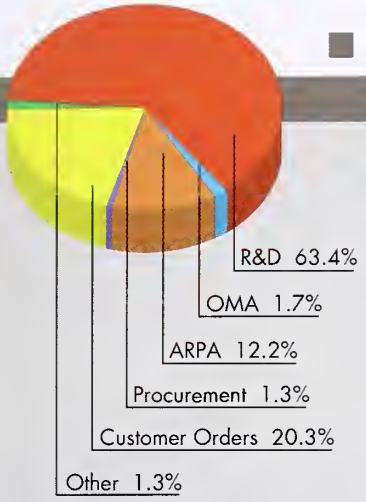
Divestitures

Over the past two years, ARL has divested over $200M in revenue in accordance with the new organization construct mandated by the Army leadership and the changed customer base. The divestitures included nonresearch areas such as fuze development and production.

Obligation/Disbursement

ARL continued its long history of exceeding all goals. In FY93, 98.3 percent of the RDTE program and 100 percent of the reimbursable program were obligated.

Statement of Operations for Fiscal Years 1992–1994

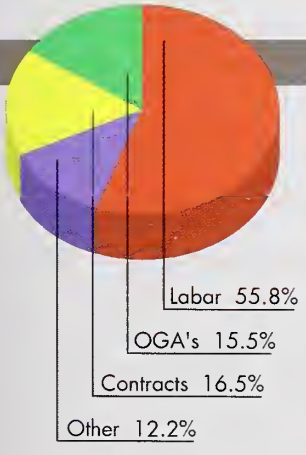


TOP TEN CUSTOMERS

PEO/PM	$42.6M
Marines	9.5
ARDEC	5.4
CECOM	5.1
ARPA	4.0
DNA	3.8
AMCCOM	3.3
SDC	2.0
STRICOM	1.9
ERDEC	.5
Total	78.1

REVENUE — $ Thousands

	FY92 Actual	FY93 Actual	FY94 Projected
RDTE:			
Basic Research	$84,713	$32,046	$38,488
Exploratory Development	114,737	174,722	142,721
Advanced Development Non-systems	26,412	32,188	4,088
Advanced Development Systems	3,521	7,269	—
Management Support	129,734	117,993	117,210
Operational Systems Development	2,848	1,749	2,100
Operations and Maintenance	9,184	9,825	—
Army Procurement Appropriation	1,122	5,736	—
Office, Secretary of Defense	35,152	2,139	3,494
Base Realignment and Closure	—	5,578	12,848
Army Family Housing	46	44	—
Advanced Research Projects Agency	61,754	70,465	50,000
Customer Orders	114,421	117,105	111,400
TOTAL REVENUE	$583,644	$576,859	$482,349



EXPENSES — $ Thousands

	FY92 Actual	FY93 Actual	FY94 Projected
Personnel Services and Benefits	$210,767	$215,982	$201,800
Travel and Transportation	10,415	9,980	9,900
Rent, Communications, and Utilities	3,896	4,874	4,800
Printing and Reproduction	82	39	—
Other Contractual Services	125,722	63,713	60,000
Orders to Other Government Agencies	34,690	60,068	55,500
Supplies and Materials	10,743	12,262	12,300
Equipment	12,220	18,7626	19,000
Land and Structures	246	1,122	1,000
Grants and Fixed Charges	1,271	39	—
TOTAL EXPENSES	$410,052	$386,841	$364,300
Net Results from Operations*	$173,592	$190,018	$118,049

* *This figure comprises undelivered orders (obligated but not yet billed) and outstanding commitments.*

Technical Review Board

Left to right

Seated

Dr. Harrison Schmitt
HARRISON SCHMITT ASSOCIATES

Dr. John Lyons
ARMY RESEARCH LABORATORY

Standing 1st row

Dr. Dennis Hall
UNIVERSITY OF ROCHESTER
INSTITUTE OF OPTICS

Dr. Thomas Hartwick
TRW SPACE AND
ELECTRONICS GROUP

Dr. H. Thomas Hahn
UNIVERSITY OF CALIFORNIA

Dr. David Barton
ANRO ENGINEERING, INC.

Dr. William C. Miller
WEST VIRGINIA UNIVERSITY

Dr. Thomas Eagar
MASSACHUSETTS INSTITUTE
OF TECHNOLOGY

Standing 2nd row

Dr. John Siegfried
PENNSYLVANIA COLLEGE
OF OPTOMETRY

Dr. Robert Rankine, Jr.
TASC

Dr. Ronald York
GENERAL MOTORS CORP.

Mr. Harry L. Reed, Jr.
SYSTEM ENGINEERING
CONSULTANT

Dr. Joe Thompson
MISSISSIPPI STATE UNIVERSITY
NATIONAL SCIENCE
FOUNDATION

Not Pictured

Dr. Walter LaBerge
UNIVERSITY OF TEXAS
INSTITUTE OF ADVANCED
TECHNOLOGY

Performance Evaluation

In order to assess the organization's overall performance, we developed a Performance Evaluation construct consisting of three primary pillars: customer surveys, metrics, and peer review. As we actively participate in the Government Performance Results Act of 1993, this construct will be used as the vehicle to record our progress.

	FY93	FY94	Long-term goal
Top 5 deliverables	100 %	100 %	100 %
Technology Program Annexes	100 %	100 %	100 %
Patents issued	63	75	90
Refereed papers	236	275	375
New Cooperative R&D Agreements	14	26	37
New Patent Licence Agreements	2	11	18
Post-doctoral Fellows	32	42	75
Guest researchers	137	150	500
Number of employees	3576	3509	2847
S&E PhDs	22 %	23 %	40 %
Training hours per employee	50	50	65
Employees on long-term training	24	35	55
Obligation/disbursement rates	96/67	96/55	96/55
Customer funding	$111M	$111M	$150M
FAST-Jr graduates	23	25	33

Performance Metrics

Implementation of the metrics pillar has been an on-going interactive process. In FY93, 15 of the 41 metrics that were agreed upon by the Directorate Executives and the Director were incorporated into FY94 performance standards.

Customer Survey

In FY93, the Directorate Executives interviewed 75 of ARL's most senior stakeholders to solicit their views and opinions about the future of ARL's organization, mission, management, and operations. The process identified areas of both contention and consensus regarding ARL's mission and performance. In FY94, we will use a short survey keyed to our Technology Program Annexes (TPAs) to determine the customers' level of satisfaction.

Peer Review

The ARL Technical Review Board (TRB) consists of 13 highly distinguished and accomplished academic and industrial experts serving as consultants to the Director, ARL. The TRB peer review panel met in June 1993 for the first time to evaluate ARL's overall technical performance and to advise the ARL Director on the quality of technical work being performed at ARL relative to state-of-the-art industry standards.

1993 Technical Recognition

HONORS

Dr. Malcolm S. Taylor	The Army Wilks Award for Contributions to Statistical Methodologies in Army Research, Development and Testing
Dr. Carl Campagnuolo	AMC Engineer of the Year
Robert Weinraub	Meritorious Civilian Service Award
Jeffrey D. Singleton	NASA Superior Accomplishment Award
Richard Stern	Lifetime Achievement Award (in Technology Transfer) from the Technology Utilization Foundation
Dr. Maurice Weiner	Elected as a Fellow of the IEEE
Dr. A. Karl Owen and Peter Meitner	Honored as Top Engineers by the Cleveland Federal Executive Board
Dr. Michael D. Hathaway	NASA Best Paper of the Year Award
Bernard Strauss	Charles W. Briggs Award from the American Society for Testing and Materials
Harold Boesch, Jr.	Honored by IEEE for breakthrough research in radiation effects in semiconductor materials and devices
Dr. John Vig	Distinguished Lecturer (1992–3) for Ultrasonics, Ferroelectric and Frequency Control Society

ARMY RESEARCH & DEVELOPMENT ACHIEVEMENT AWARDS

Dr. Joseph Nemarich	Millimeter Wave Radar Technology
Dr. Arthur Ballato Owen P. Leyden Dr. John A. Kosinski Edward R. Baidy	High Power Microwave Protection
Dr. Michael Binder Dr. Robert J. Mammone William L. Wade, Jr.	High Energy Density Capacitors
Dr. K. K. Choi Monica Taysing-Lara Wayne Chang	Infrared Hot Electron Transfer
Muhammed Mizan Dana Struzebecher Thomas P. Higgins	Ultra-Low Phase Noise, Temperature Stable Exciter Sources
Walter R. Buchwald Dr. Kenneth A. Jones Dr. Stephen N. Schauer	Identification of Key Problems Associated with Fielding the Next Generation of Optoelectronic Integrated Circuits

Patents, CRDAs, and PLAs

Patents

Initiated Dielectric Breakdown Switch
Donald Hunter
Patent No. 5,249,095—*Issued* 09/28/93

Training Grenade
Carl Campagnuolo, Donald Gross, Wesley Clark
Patent No. 5,246,372—*Issued* 09/21/93

Apparatus and Method for Testing the Response of Cardiac Pacemakers to Electromagnetic Interference
Vincent Ellis, Charles Brown
Patent No. 5,246,000—*Issued* 09/21/93

Generic Electronic Safe and Arm
Donald Hunter
Patent No. 5,245,926—*Issued* 09/21/93

Continous Bore Evacuation System
Mark Bundy
Patent No. 5,245,905—*Issued* 09/21/93

Periodic Permanent Magnet Structure for Accelerating Charged Particles
Herbert A. Leupold
Patent No. 5,245,621—*Issued* 09/14/93

Microstrip Frequency-Scan Antenna
Richard A. Stern, Richard W. Babbitt
Statutory Invention Registration: H1230—*Published* 09/07/93

Microstrip Electronic Scan Antenna Array
Richard A. Stern, Richard W. Babbitt
Patent No. 5,243,354—*Issued* 09/07/93

SAW Transducer with Coplanar Waveguide Transition
Elio A. Mariani
Patent No. 5,239,517—*Issued* 08/24/93

Flexible Solid Electrolyte for Use in Solid State Cells and Solid State Cells Including Said Flexible Solid Electrolyte
Edward J. Plichta, Wishvender K. Behl
Patent No. 5,238,759—*Issued* 08/24/93

Low-Cost, Low-Noise, Temperature-Stable, Tunable Dielectric Resonator Oscillator
Muhammad A. Mizan, Raymond C. McGowan
Patent No. 5,233,319—*Issued* 08/03/93

Ultra-Wideband High Power Photon-Triggered Frequency Independent Radiator
Anderson H. Kim, Leo D. DiDomenico, Maurice Weiner, Louis J. Jasper, Jr., Robert J. Youmans, Thomas E. Koscica
Patent No. 5,227,621—*Issued* 07/13/93

Liquid-Pressurized Radio Frequency Interference Gasket
Youn Lee, Bruce Benwell, John Latess
Patent No. 5,225,631—*Issued* 07/6/93

Optically Controlled Resonant Tunnel Diode Oscillator
James F. Harvey, Robert A. Lux, Thomas P. Higgins, Arthur Paolella, Dana J. Sturzebecher
Patent No. 5,223,802—*Issued* 06/29/93

Method of Treating a Gallium Arsenide Surface and Gallium Arsenide Surface So Treated
Gary J. Gerardi, Edward H. Poindexter, Fang Rong
Patent No. 5,219,797—*Issued* 06/15/93

Optical Deflection Device
William Fellows
Patent No. 5,216,535—*Issued* 06/01/93

Magnetic Field Sources Having Non-Distorting Access Ports
Herbert A. Leupold
Patent No. 5,216,401—*Issued* 06/01/93

Magnetic Field Sources for Producing High-Intensity Variable Fields
Herbert A. Leupold
Patent No. 5,216,400—*Issued* 06/01/93

Quarter Wave High Voltage DC Block Covered with a Polyurethane Insulating Layer
Richard W. Babbitt, William C. Drach, Thomas E. Koscica
Patent No. 5,216,395—*Issued* 06/01/93

Method of Creating X-Rays from a Pulsed Laser Source Using a Gaseous Medium
Richard A. Neifeld
Statutory Invention Registration: H1200—*Published* 06/01/93

Color Night Vision Camera System
Yue T. Chiu, Philip F. Krzyzkowski, Richard P. Tuttle
Patent No. 5,214,503—*Issued* 05/25/93

Pressure Stabilized Radio Frequency Gasket
Bruce Benwell
Patent No. 5,214,241—*Issued* 05/25/93

Planar Ferro-Electric Phase
Richard W. Babbitt, William C. Drach, Thomas E. Koscica
Patent No. 5,212,463—*Issued* 05/18/93

In-Situ Sensor Method and Device
Shawn Walsh
Patent No. 5,210,499—*Issued* 05/11/93

Optical Modulator Based on Gamma-X Valley Mixing in GaAs-AlAs
Mitra Dutta
Patent No. 5,208,695—*Issued* 05/04/93

Antipersonnel Training Mine
Carl Campagnuolo
Patent No. 5,207,579—*Issued* 05/04/93

Method of Treating the Surface of Commercially Available Polymer Films
William L. Wade, Jr., Robert J. Mammone, Michael Binder
Statutory Invention Registration: H1164—*Published* 04/06/93

Apparatus and Method for Interfacing Indirect-Fire Devices with MILES
Carl Campagnuolo, Jerome Gerber, Wesley Clark
Patent No. 5,199,874—*Issued* 04/06/93

Wide-Range Multicolor IR Detector
Doran D. Smith, Mitra Dutta, Kwong-Kit Choi
Patent No. 5,198,659—*Issued* 03/30/93

Variable Volume Flushing Device for Water Conservation
Louis Jasper, Jr.
Patent No. 5,197,151—*Issued* 03/30/93

Non-Shearing Connectors for Flexible Circuits
Brian Mary
Patent No. 5,195,898—*Issued* 03/23/93

Sabot for High Dispersion Shot Shell
Lawrence Puckett
Patent No. 5,192,830—*Issued* 03/09/93

Microwave Projectile
Louis Jasper, Jr.
Patent No. 5,192,827—*Issued* 03/09/93

Sabot for High Dispersion Shot Shell
Lawrence Puckett
Patent No. 5,191,168—*Issued* 03/02/93

Multi-Point Fiber Optic Igniter
George Mon
Patent No. 5,190,099—*Issued* 03/02/93

Pulsatile Impinging Cooling System for Electronic IC Modules and Systems Using Fluidic Oscillators
Richard Beyer
Patent No. 5,191,167—*Issued* 03/02/93

Slotted Microstrip Electronic Scan Antenna
Richard A. Stern, Richard W. Babbitt
Patent No. 5,189,433—*Issued* 02/23/93

Inductive Cable Resistance Tester
John E. Tuttle
Patent No. 5,189,375—*Issued* 02/23/93

Sabot for High Dispersion Shot Shell
Lawrence Puckett
Patent No. 5,189,251—*Issued* 02/23/93

Thermally and Mechanically Stable Muzzle Reference System Collimator Assembly
Mark Bundy
Patent No. 5,189,245—*Issued* 02/23/93

Microstrip High Reverse Loss Isolator
Richard A. Stern, Richard W. Babbitt
Patent No. 5,180,997—*Issued* 01/05/93

Optically Activated Hybrid Pulser with Patterned Radiating Element
Anderson H. Kim, Maurice Weiner, Louis J. Jasper, Jr., Thomas E. Koscica, Robert J. Youmans
Patent No. 5,177,486—*Issued* 01/05/93

Microstrip Ferrite Circulator for Substrate Transitioning
Richard A. Stern, Richard W. Babbitt
Patent No. 5,177,456—*Issued* 01/05/93

Method for the Multi-Material Construction of Shaped-Charge Liners
William Walters, Stanley Golaski, Pei Chou
Patent No. 5,175,391—*Issued* 12/29/92

Microstrip-to-Inverted-Microstrip Transition
Richard W. Babbitt, Thomas E. Koscica, Adam Rachlin
Patent No. 5,173,666—*Issued* 12/22/92

Detonator Ignition Circuitry
Christopher G. Braun
Patent No. 5,173,570—*Issued* 12/22/92

Sweeping Photoreflectance Spectroscopy
Mitra Dutta, Hongen Shen
Patent No. 5,172,191—*Issued* 12/15/92

Head Support Stand Adjustable by Compound Turnbuckle
Bruce Amrein, Jeffery Nickel
Patent No. 5,165,137—*Issued* 11/24/92

Frangible Sabot
Todd Bjerke, William Edmanson, Jr.
Patent No. 5,165,041—*Issued* 11/17/92

Fluidic Sonar Sensor
Michael Scanlon, Stephen M. Tenney, Nassy Srour, James Joyce
Patent No. 5,164,919—*Issued* 11/17/92

Method of Enhancing the Electrical Conductivity of Indium-Tin-Oxide Electrode Stripes
Robert J. Zeto, Otto J. Gregory, Richard C. Piekarz
Patent No. 5,163,220—*Issued* 11/17/92

Cantilevered Air-Gap Type Thin Film Piezoelectric Resonator
Elio A. Mariani, Raymond McGowan
Patent No. 5,162,691—*Issued* 11/10/92

Optical Control of a Microwave Switch
Dana J. Sturzebecher, Arthur Paolella, Thomas P. Higgins
Patent No. 5,162,657—*Issued* 11/10/92

Apparatus for Compaction of Ceramic
Andrus Niller, Gerald Moss, Robert Eichelberger
Patent No. 5,162,118—*Issued* 11/10/92

Microstrip Circuit with Transition for Different Dielectric Materials
Richard W. Babbitt, Richard A. Stern
Patent No. 5.160,904—*Issued* 11/03/92

Battery Connector and Method
Bruce A. Testa, Arnold Bard
Patent No. 5,158,477—*Issued* 10/27/92

Optical AND/OR Gate Employing Non-Linear Organic Polymers and Photovoltaic/Piezo-Electric Optical Interfaces
William Fellows
Patent No. 5,155,619—*Issued* 10/13/92

Optically Activated Sub-Nanosecond Hybrid Pulser
Anderson H. Kim, Maurice Weiner, Robert J. Youmans, Robert J. Zeto, Louis J. Jasper, Jr.
Patent No. 5,155,352—*Issued* 10/13/92

Flexible Solid Electrolyte Separator for Use in a High Temperature Electrochemical Cell, Method of Making the Separator, and Electrochemical Cell Including the Separator
Edward J. Plichta, Wishvender K. Behl
Patent No. 5,154,991—*Issued* 10/13/92

Rechargeable Solid Lithium Ion Electrochemical System
Edward J. Plichta, Wishvender K. Behl
Patent No. 5,154,990—*Issued* 10/13/92

Silicon Shadow Mask
Bernard Rod, Theodore Blomquist, Judith McCullen, Bohdan Dobriansky
Patent No. 5,154,797—*Issued* 10/13/92

Acoustic Vibrator with Variable Sensitivity to External Acceleration
John A. Kosinski
Patent No. 5,153,476—*Issued* 10/06/92

Triggering Technique for Multi-Electrode Spark Gap Switch
Lawrence J. Bovino, William H. Wright
Patent No. 5,153,460—*Issued* 10/06/92

High Power, Solid State RF Pulse Generators
Lawrence J. Bovino, Maurice Weiner, Anderson H. Kim
Patent No. 5,153,442—*Issued* 10/06/92

Cooperative Research & Development Agreements (CRDAs)

Prevention of Stall in Axial Flow Compressors
No. 9309-A-C298—*Accepted:* 09/30/93
Partner: University of Maryland, College Park, MD

D-Shaped Fibers with Integrated Circuits
No. 9309-A-C297—*Accepted:* 09/30/93
Partner: Ceramoptec, Inc., Enfield, CT

Electrostatic Sensor for the 120mm Main Tank Gun
No. 9309-A-C296—*Accepted:* 09/23/93
Partner: Alliant Techsystems, Inc., Hopkins, MN

Adaptive Antenna Processor Using Both Maximin Recursive Suppression Algorithms
No. 9306-A-C280—*Accepted:* 07/08/93
Partner: Cubic Defense Systems, San Diego, CA

Permanent Magnet Designs for Use in Magnetic Resonance Imaging Systems
No. 9306-A-C279—*Accepted:* 06/25/93
Partner: Research & Resources, Inc., Milwaukee, WI

Microcomputer Compensated Crystal Oscillator
No. 9306-A-C278—*Accepted:* 06/23/93
Partner: Q-Tech Corporation, Culver City, CA

Piezoelectric Materials with Application to Frequency Control and Signal Processing Systems
No. 9305-A-C274—*Accepted:* 05/26/93
Partner: RF Monolithics, Inc., Dallas, TX

Induction Heat Treatment of Steel Armor
No. 9305-A-C273—*Accepted:* 06/10/93
Partner: TOCCO, Inc., Madison Heights, MI

State of Charge Indicator for High Energy Lithium Batteries
No. 9303-A-C261—*Accepted:* 04/21/93
Partner: Power Conversion, Inc., Elmwood, NJ

High Power Control Components and Systems
No. 9301-A-C246—*Accepted:* 02/12/93
Partner: Colorado School of Mines, Golden, CO

Display Evaluation Procedures and Phosphor Display Technologies
No. 9301-A-C245—*Accepted:* 02/12/93
Partner: National Information Display Laboratory, Princeton, NJ

Electron Waveguides and Coulomb Blockage Devices
No. 9301-A-C244—*Accepted:* 02/12/93
Partner: Kean College of NJ, Union, NJ

Composite Materials Manufacturing Sciences
No. 9212-A-C241—*Accepted:* 01/14/93
Partner: University of Delaware, Newark, DE

Ion Projection Lithography
No. 9211-A-C234—*Accepted:* 12/07/92
Partner: Advanced Lithography Group, Rockville, MD

Improved Processing Methods for Fabricating Parts From Composite Materials
No. 9208-A-C209—*Accepted:* 12/17/92
Partner: Assembly Guidance Systems, Waltham, MA

Patent License Agreements (PLAs)

Low Cost, Low Noise, Temperature-Stable, Turnable Dielectric Resonator Oscillator
No. 9307-A-P286—*Accepted:* 07/28/93
Partner: Techtrol Cyclonetics

Permanent Magnet Designs Used in Microwave Tubes
No. 9306-A-P283—*Accepted:* 07/13/93
Partner: Martin Marietta Corporation

ARL Business Area Emphasis	Budget	Work Force	S&Es
Advanced Computational & Information Sciences	**10M**	**123**	**71**
• High-performance computing and communication networking			
• Software technology (massively parallel processing, scalable architecture)			
• Simulation technology (virtual factory, virtual reality, scientific visualization)			
Battlefield Environment	**23M**	**147**	**96**
• Tactical commander decision aids to "own the weather"			
• Atmospheric and environmental 3D modeling to mitigate "regional" environmental battlefield pollution			
Electronics & Power Sources	**46M**	**327**	**231**
• Research, development, and integration of advanced electronic devices			
• Battery/fuel-cell technology for future soldier missions			
Human Research & Engineering	**20M**	**202**	**136**
• Visual and auditory enhancements for the soldier			
• Cognitive and decision aids for commanders and soldiers			
• Decision support systems for tactical and logistics staffs			
Materials	**25M**	**315**	**228**
• Biomaterials for lightweight personal protection			
• "Smart" materials and intelligent processing for lower cost composites			
Sensors, Signatures, Signal & Information Processing	**44M**	**451**	**294**
• Sensors and models for automatic target recognition for commanders on the move			
• Orders of magnitude increase in signal processing using optics			
Survivability/Lethality Analysis	**46M**	**429**	**324**
• Development of tools, techniques, and methodologies for SLA			
• Integrated survivability/lethality analyses			
Vehicle Propulsion	**6M**	**51**	**35**
• Alternative cycle engine technology (e.g., turbine/diesel)			
• Applications for high-temperature materials			
• Alternative/hybrid power transfer technology			
Vehicle Structures	**5M**	**56**	**38**
• Improved structural integrity through advanced analyses, predictive modeling			
• Advanced design methods for composite structures			
• Rotorcraft vibration and noise control			
Weapons Technology	**95M**	**543**	**378**
• Integrated survivability (active protection, low-observability technology, high-power microwave technology, vulnerability analysis)			
• Enhanced lethality, smart, and hypervelocity weapons/munitions			
• Environmental pollution prevention research			

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